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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XLI.—*The Invisible Solar and Lunar Spectrum;** by S. P. LANGLEY. With Plates IX, X.

THE following investigation has been made from studies at the Allegheny Observatory, but it is proper to state that the provision of the very special apparatus used, is due to the liberality of a citizen of Pittsburgh, who has desired that his name should not be mentioned.

This paper is an abstract of a forthcoming memoir, which will eventually appear in the fourth volume of the publications of the United States Academy of Sciences, to which the reader is referred for fuller details.

Ever since the writer first† investigated the infra-red of the solar spectrum to the extent of about three microns, he has assumed, from all analogy, the probable existence of solar heat of still greater wave-lengths, which, however, he has not till lately been able to experimentally demonstrate, so that there has been a doubt whether such waves were emitted by the sun after absorption by its own atmosphere, or whether they existed pre-

* As the writer has already presented to the National Academy a memoir (read October 17, 1884, Memoirs Nat. Acad. of Sci., vol. iii,) on the heat of the moon, in which he spoke of investigations still in progress on it, it should be said that these are not yet published, and that they are only given here so far as is necessary in explanation of certain anomalies in the infra-red solar heat-spectrum, which forms the principal subject of the present paper.

† Comptes Rendus de l'Institut de France, September 11, 1882. Amer. Jour. Science, March, 1883.

viously to absorption by the earth's atmosphere, and, owing to the action of the latter, never reached us. Below the point $2^{\mu}\cdot8$, to which the maps published in 1882 and 1883 extended, it was stated, however, at that time, that there had apparently been detected feeble, or more properly speaking, dubious, indications of solar energy. This doubt arose partly from this extreme feebleness here of the heat itself, partly from lack of the usual experimental means, since the glass of our prisms (which, as we had discovered, transmitted the greater part of all the sun's invisible heat then known) absorbed this, while no maker could then supply its place with suitable rock salt; and, most of all, from a difficulty of a less familiar kind, but which should from its importance be clearly apprehended by the reader. This is, that even if we could recognize that some feeble invisible heat existed, there were then no means of determining that it really belonged to the part of the spectrum where it was found, and was not intruded invisible heat of a more refrangible kind, diffused from its proper place in the upper spectrum by the inevitable defects in the action of spectroscopic apparatus.

In 1884 and 1885, while investigating the invisible spectrum of the sunlit side of the *moon*, we first found evidence of heat in this region from any extra-terrestrial source—heat whose enormous wave-length was comparable to that chiefly radiated from ice, which was also experimented on. This was so far distinct from the reflected solar heat of greater refrangibility, which occupied its own part of the spectrum, that our experiments indicated that this lunar heat was mainly not reflected, but radiated from a surface at a low temperature. But the chief anomaly was that while we had thus definitely recognized this kind of heat in the extremely feeble heat-spectrum of the moon, we had not yet done so in the far stronger solar one, or, as I observed at the time, that "we here *seem* to have heat from the moon of lower wave-length than from the sun."

I do not state (it must be observed) that the sun's heat here is less than the moon's, but that what there is is harder to recognize. It is not easy to give an adequate idea of the difficulties of observation which lead to this apparently paradoxical result, particularly as physicists are so far from having yet investigated this region that even the barriers which have closed it to research are themselves of an unfamiliar kind. I can perhaps best illustrate it by analogy. Every spectroscopist knows how very hard it is to view the lines below A, and that even A itself, though very large, is not an easy object to see without special precautions. This arises not so much from the fact that the very deep red light here, like that of dull glowing iron, feebly effects the eye, but, in a still greater degree, because

yellow and orange light exists in relatively enormous quantity in the neighboring parts of the visible spectrum, and irregularly diffused and reflected portions of this light re-appear where they do not belong and overpower the radiation legitimately there. Still, we can put a colored glass before the slit and cut off the intruding light in a great measure, and we can *see* the extraneous light which comes in, and allow in some degree for its effects; but here, in the actual case of the unseen heat in the far more remote spectral region we are about to describe, all radiations, both the feeble ones we would study and the intruders on them which we would avoid, are alike invisible, and we are, of course, unable in any case to use glass, since this is opaque to all the rays now in question. If any one familiar with the visible spectrum will imagine himself as trying to discriminate with his *eyes shut* between these different components of the apparent radiation just below Fraunhofer's A, and endeavoring while blindfold to say how much of it legitimately belongs there and how much does not, he will have a better conception of the difficulties peculiar to our actual field of research, though still an inadequate one, since the total heat radiation here is at best less than the hundredth part of that in the vicinity of the A line, which we have used in illustration.

For the clearer understanding of this, I must, in anticipation of what follows, remark that while in the solar spectrum the maximum heat, as we all know, appears not very far from the red, so that the heat corresponding in a general sense to the short waves is great, and to the still longer ones small, in the lunar invisible spectrum the reverse is the case; for here, speaking generally, the solar reflected heat found in the upper part of the lunar spectrum is less than the heat apparently radiated from the moon's own soil, which is of great wave-length, and which we have found in the extreme region of the spectrum we are now studying. In other words, the typical solar spectrum heat is greatest in the relatively short wave-length; the typical lunar spectrum heat is greatest in the long wave-lengths. The explanation of the curious fact that this particular quality of heat may be more easily recognized where it exists in a less degree in a lunar spectrum than where it is found in a relatively great degree as in the solar, will be still clearer if we consent (in continuance of the illustration) to further compare this lunar invisible radiation of great wave length to the deep-red light from a piece of scarcely luminous hot iron. This peculiarly deep red is seen with little difficulty in the iron in a dark room, but never in daylight; yet it is of a quality which we know from theory must exist in far greater degree in the daylight itself; nor do we, even when we would isolate it in a certain part of the solar spectrum, see it there,

because it is now obscured by the inevitable diffusion or reflection of part of the neighboring brilliant light which the prism ought to keep wholly away, but (owing to inevitable instrumental defects) does not. The dull glowing iron carries no white light along with it, and therefore its feeble peculiarly deep red is easier seen than the far stronger corresponding red in the solar spectrum.

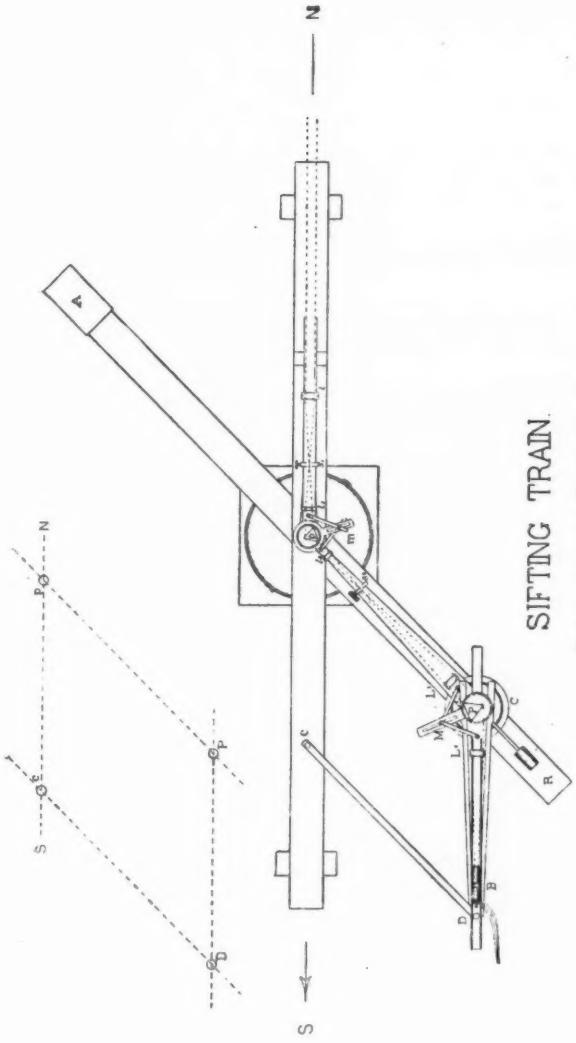
By the aid of this analogy in the case of light, and passing now to the actual case of wholly invisible radiation, I hope it may be clear how the feebler heat in the lunar extreme infra-red spectrum was at first recognized more easily than the stronger corresponding heat in that of the sun.

It may be asked why (if we cannot cut off the diffused heat in the solar infra-red spectrum by the use of an absorbing glass) we cannot put a prism in front of the slit after the plan of Helmholtz. This is practically impossible here (owing to instrumental conditions which we need not now explain), unless we find some way of keeping the axis of the spectro-bolometer either motionless or always parallel to itself, in spite of the varying direction of the rays from such a prism, and of automatically limiting the kind of radiation to be observed in any part of the spectrum, to that legitimately belonging there. The following arrangement was, after various trials, adopted with success. Its immediate purpose is to overcome the difficulty which we have just explained at such length; that is, to sift out the extraneous heat which remains after the ordinary action of the prism, but it can of course be used for light also.

Description of Sifting Train. (See fig. 1.)

Let N S be a massive beam, resting on two piers, and immovably fixed in the meridian. Let A R be a second beam, movable on a turn-table, placed centrally beneath N S. Temporarily mounted on A R, and moving about with it, is the large spectro-bolometer described in a previous memoir. The center of its graduated circle (C) lies under the point P. Its two long arms are not free to move as usual, but are constrained by mechanical attachments (not here shown) to occupy the positions P*p*, PD.

Two large 60° prisms of the same material (pure rock salt from the same mine), their faces worked with the greatest accuracy, are placed with these equal refracting angles in opposite directions, one (P) at the obtuse, the other (*p*) at the acute angle of the parallelogram (P*p* D*c*), the vertices of all whose angles in the mechanical construction are pivoted and connected by inflexible arms, so that (both prisms being kept automatically in minimum deviation by the attachments M, *m*) the angle of minimum deviation (*c p* P) for the first prism is



SIFTING TRAIN.

Solar-Lunar Spectrum.

FIGURE 1.

S.P.LANGLEY

necessarily equal to the angle of minimum deviation (R P D, or its equal P D*c*).

Thus, if the pencil of solar radiation reflected from a large siderostat on the north, not shown here, passes from N toward S, on moving the beam A R, pivoted at *p* (*p* being the projection in our drawing of a vertical line passing through the center of the turn-table and the median line of N S and A R) into various positions, N S remaining fixed, the rays, which are refracted by the prism *p* in the direction of *p* P, will emerge from P in the direction P D and fall upon the bolometer B. A condensing lens (*l*) forms the solar image on the slit (s_1) of the first spectroscope, whose train (consisting of collimator, l_1, prism, *p*, and image-forming lens, l_2) forms a spectrum on the slit (s_2) of the second spectroscope. Here a narrow pencil from the first spectrum comprising *only* the particular wave-lengths which fall within the width of s_2, is admitted, and, by the second train L_1 P L_2, formed into a horizontal spectrum at and on either side of B. When we move A R this spectrum moves in turn past the vertical linear thread of the bolometer B, which lies in the focal plane of this spectrum, and is immersed in its successive absorption lines as these defile past it. The function of the first spectroscopic train (l, l_1, p, l_2) is solely to sift out the extraneous radiations and to present at the second slit (s_2) only those which legitimately belong to that part of the spectrum we wish to study. These pure rays pass into the second slit and are analyzed by the second train in the usual way, by the aid of the linear bolometer at B, and of the circle (C) reading to ten seconds of arc.

The objection to this apparatus is its complexity, which, however, we have been unable to advantageously diminish. We may, however, satisfy ourselves by visual observation of the Fraunhofer lines seen through the whole compound system; (entirely of salt) both of the optical perfection of the surfaces of our entire double train, and of the accuracy of its purely automatic action.

Results of Observation.

With this and the apparatus already described in previous memoirs we have searched the extreme infra-red solar spectrum at first without definite success, later with results which will be better understood by the accompanying drawings.* Fig. 2*b* shows the newly investigated invisible solar heat spectrum on the normal scale up to an (estimated) wave-length of 18^{μ}. Fig. 3*a* is an enlarged view of that portion of it, extending to 5^{μ} and fig. 3*b*, a photographic interpretation of the last, obtained automatically by a special device; so as to present somewhat

* For figs. 2*a*, 2*b*, 3*a*, 3*b*, see Plates IX, X.

the appearance which this heat region might be expected to show to an eye which could see it.

Inordinately long as our new chart fig. 2*b* may seem, we see that the scale is, nevertheless, contracted to the last degree, so that the entire visible spectrum is compressed into less than 0.2 of an inch, seen on the left or violet end. Next we have the solar infra-red, already described and shown to exist to $2^{\mu}\cdot 8$, which includes its great absorption bands, Φ, Ψ, Ω, previously investigated with glass prisms.

The principal lunar heat lies chiefly beyond the great wave-length of $0^{mm}\cdot 01$ (10^{μ}), and ere we reach it we pass over a region between 5^{μ} and 11^{μ} (many times the length of the entire visible spectrum), where the solar heat seems to have been, to our present means of recognition, entirely absorbed, probably chiefly by our own atmosphere.

It will be convenient, however, after noting the extent of the whole region shown in fig. 2*a*, to commence our description with the detailed portion shown in figures 3*a* and 3*b*, to which the reader is referred in illustration of what immediately follows.

The lowest bands already described, as seen in the spectrum of a flint glass prism, are the small ones ω_1, and ω_2, near 2^{μ}. Below this point all is believed to be here given for the first time. The bands in this new region are undoubtedly due, chiefly, if not wholly, to telluric absorption, and they are notably variable, depending on the season of the year and still more on the hour of the day. As the sun sinks, its rays, passing through increasing air masses, suffer absorptions which singularly change the appearance of the bands; as is shown in figures 4 and 5 which, however, are drawn upon the prismatic, not the normal, scale. Figure 4 is identifiable with the portion extending from X to Y on the latter.

Observations made during the winter indicate that the band at $2^{\mu}\cdot 64$, figures 3*a*, 3*b*, is, with a high sun, largely filled up, especially on the less refrangible side. At noon a subordinate maximum has been found within the low sun limits of this band at $2^{\mu}\cdot 94$, and a second one at $2^{\mu}\cdot 80$ frequently accompanies it, producing subordinate minima at $2^{\mu}\cdot 89$ and $3^{\mu}\cdot 02$. As the absorption increases, with a sinking sun, these subordinate maxima disappear to a very great extent, that at $2^{\mu}\cdot 80$ being the first to vanish as well as the quickest to grow, so that at noon, on a cold day, it not only surpasses the maximum at $2^{\mu}\cdot 94$, but even begins to approach that at $3^{\mu}\cdot 20$, while, when the sun's altitude is less than 10° the nearly uniform

part of the band extends from $2^{\mu}\cdot45$ to $3^{\mu}\cdot15$ without a break. Minor cold bands at $3^{\mu}\cdot37$ and $3^{\mu}\cdot69$ are suspected. The evidence for their existence may be seen by inspecting the high sun and low sun curves given in fig. 4. From $4^{\mu}\cdot0$ to $4^{\mu}\cdot5$ we have another region of almost complete absorption, followed by a maximum at $4^{\mu}\cdot6$, beyond which lies the longest break of all, stretching from 5^{μ} to 11^{μ}. The solar heat throughout the region from 5^{μ} to 11^{μ} is probably far greater than it here appears, and if the parts struck out by our atmosphere were restored it would probably be found that a not wholly inconsiderable portion of the sun's heat lies in this region, for it must be borne in mind that even the maxima are doubtless in some degree affected by a linear absorption, so that, because a part of the spectrum appears to be almost entirely transmitted, we cannot infer that it necessarily is so, or that it has not, after passing through the upper strata of the air, already parted with a considerable portion of its energy. While the position of a line or band caused by light from the center of the sun is, in the upper spectrum, unchangeable, in this extreme lower spectrum (if we could photograph it, like the upper, on cold and on hot days, with high sun and with low), the absorption would be seen to increase, not symmetrically with the center of the band, but more on one side than another, so as to considerably modify the position of greatest absorption. This seems to be the explanation of a curious fact, which could not have been anticipated in advance of observation; that is, that the centers of several of these bands and lines are under some conditions found to be shifted to a recognizable extent, and hence their wave-lengths are, within certain limits, variable.

It seems as though the absorption, which we see exercised in most of the visible spectrum by fine lines, which begin already to show aggregation into a broader absorption band on the borders of the infra-red (*e. g.*, the well-known "A" of Fraunhofer), is, as we pass farther down into the invisible part, represented by wider and wider bands, like Φ, Ψ, Ω (composed themselves of lines probably). The heat between these local regions of almost total absorption continues, as I have repeatedly before stated, to be (contrary to the old belief) apparently transmitted with even greater facility than that in the visible spectrum. These bands have grown larger, and closer and closer together, as we have come down from the visible spectrum below the point where the old map ended, and not far below 5^{μ} they seem to practically coalesce into one almost unlimited cold band. We do not, let it be observed, assert that the absorption is absolutely total even here, and, in fact,

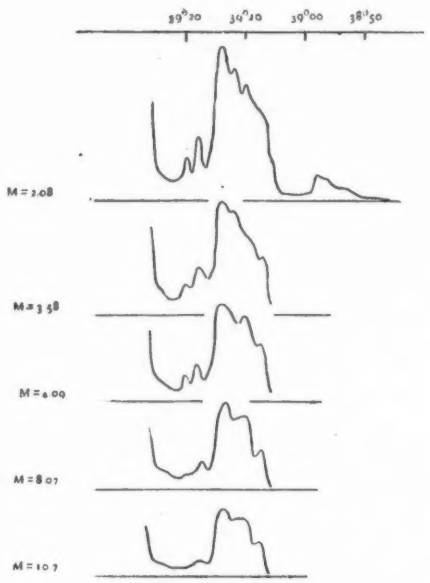


FIGURE 4 Absorption and Air Mass.
Allegheny Observatory, January 22d 1887

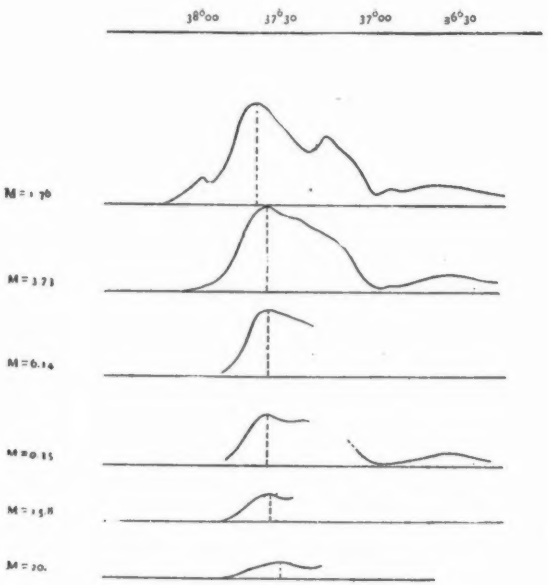


FIGURE 5. Absorption and Air Mass.
Allegheny Observatory, February 19th, 1887

there is always a feeble heat to be observed throughout this extent. This, however, the use of the sifting train shows to be largely, at any rate, factitious, but we admit the possibility that subsequent research may prove that it is not all so.

Let us now recur to fig. 2*b*, where we shall find below 10^{μ} the same dependence of the effects upon the season and the hour, as in the part above 5^{μ}. At $10^{\mu}{\cdot}2$ observations made during the autumn showed scarcely the feeblest suspicions of heat, and the same has held good in the very mild weather of the past winter (of 1887); but on a few days, when the temperature had fallen below the freezing point, a notable maximum was found at this point, followed by a minimum at $10^{\mu}{\cdot}7$. The height of this maximum relatively to the principal one in this region at about 13^{μ} appears to be correlated with the composition of the air as affected by the temperature. On the coldest day (temperature at noon—6·7° C.) the deflection at midday for $\lambda = 10^{\mu}{\cdot}2$ was nearly one-half that at 13^{μ}, but on other days, when the temperature was near 0° C., the deflection at $10^{\mu}{\cdot}2$ did not exceed one-fourth that at 13^{μ}, while at temperatures above +10° C. it was not noticeable.

It is in the region near 13^{μ} to 14^{μ}, or over twenty times the length of the visible spectrum below it, that we have found the maximum of the lunar heat spectrum, and it is here that we first obtained indications of solar radiation corresponding in its great wave-length to this special lunar radiation, but of amounts non-estimable by the means till now employed. I have already spoken of its almost unrecognizably small amount, and a perhaps more vivid apprehension of its extreme minuteness will be gained from the statement that on this graphical construction, on the scale of ordinates used in delineating the curve from 0 to 5^{μ}, no heat appears below 5^{μ} anywhere, not even at the maximum near 13^{μ} and 14^{μ}; because, though heat exists to the bolometer, the highest ordinate which would represent it on our drawing is not so great as the *thickness* of the thin black line, which denotes the axis of abscissæ. I have accordingly here been obliged to exhibit it separately by a dotted curve whose ordinates are one hundred times those in the remainder of the spectrum. The points of minima in it are identifiable with absorption bands, which we have directly observed, and which we have independently found to exist in our own atmosphere, by studying the radiations from a copper surface, one meter square, at the temperature of boiling water placed in the open air at a distance of one hundred meters from the bolometer. (The description of this will be found in

a supplementary research to be given elsewhere.) The principal lunar heat then is found here, at a point of the spectrum corresponding to the maximum radiations from melting ice, but its maximum amount is probably less than 1 per cent of the corresponding solar heat, which we have just found to be itself so small. That we can detect the lunar heat at all under these circumstances is due to the fact that we are here able to employ for it very short-focused mirrors and lenses, which condense it into a very short and relatively hot spectrum (there being no fear of their diffusing extraneous heat, since none worth mention exists). In the case of the sun we must employ a wholly different optical train, forming a far longer spectrum. It will be easily understood that these means, which enable us to determine the position of the solar and lunar heat maxima here are not favorable to a determination of the relative amounts of heat received from the sun and moon under such different conditions. We can only say that these ratios are themselves utterly changed from what they are in the visible spectrum, where we all know that the solar *light* is something like five hundred thousand times moonlight. It is probable that the solar heat received in *this* part of the spectrum is less than five hundred times the lunar; but the actual ratio is only very roughly determinable by our present means.

By comparison with the "heat" spectra given in a previous memoir, we may also note the fact that some of the wave-lengths given from ice, are identifiable in the solar spectrum, nor (in view of the now established fact that the *ratios* of the heat, at like parts of the spectra of two unequally hot bodies, are functions of the wave-length) need it surprise us, that we have also found that this part of the spectrum of the sun, is not incomparably hotter than the corresponding part of the ice-spectrum.

It may be asked if we can, after all, feel sure of the character of such minute amounts of heat in the presence of the already described reflected and diffused heat from the upper spectrum, considering the possibility that something may go wrong in the elaborate arrangement of the sifting train, and leave us (as everything we study now is invisible) without ocular warning of the fact. I may reply that we have lately found an admirable check upon the efficiency of our optical devices in the behavior of that familiar substance lamp-black, which all physicists use either on thermometers, thermopiles, or bolometers. All of us know probably that it is not absolutely non-selective, as it used to be thought, and that it has a tendency to transmit the infra-red with greater freedom than the visible spectrum, but the statement I am about to make may excite surprise. It is, that when a very perfectly polished

rock-salt plate is covered by a sheet of lamp-black of such thickness as to transmit less than one per cent of ordinary white light, it transmits about 90 per cent of the radiations belonging to these extreme wave-lengths. In other words, it has become a transparent body to rays of this wave-length, while it exercises an intermediate degree of absorption on intermediate rays, so that by the amount of their absorption by lamp-black, we have a test by which these latter may be independently identified.

We have given the preceding study not only to map new lines and bands in the region between 3^{μ} and 5^{μ}, but also to verify the existence of an all but infinitesimal amount of heat at much greater wave-lengths. We have applied great pains to this latter, not so much on account of its own importance, as on account of the important conclusions to be drawn from it later; for if it is true that in this extreme spectral region, corresponding to temperatures much below the boiling point and even below that of melting ice, the amount of the solar heat is trivial, it is also true that the fact of its existing at all is of very significant interest to the meteorologist; for it is obviously here, at temperatures below 100° C., that the rays which make up the nocturnal as well as diurnal radiations from the soil of our own planet are to be found. We observe that if such rays can enter the air from the sun, they can go out even from an icy soil (and still more from an ordinary one), to whose radiations it hence appears the atmosphere is not unpermeable. Heat, then, apparently escapes in some very minute degree even from the surface of the Arctic Zone, not only by convection but by direct radiation through the atmosphere toward space. Meteorological questions of great interest, to which we shall return in a later memoir, can best be answered from a study of this spectral region, and even if the problem of the lunar temperature did not interest us as students of celestial physics, we should still find others depending on it of very practical import.

As to the degree of accuracy obtainable in fixing its position in the spectrum, we may remind the reader that the old formulæ of Cauchy and others being useless, as we have shown, we have already undertaken a research* to enable us to determine such wave-lengths in this region. We have determined all the wave-lengths by the interpolating curve made from the observations of 1887, which has been exhibited to the Academy at its April meeting. In this memoir will be found all the explanations we can offer relating to the degree of trustworthiness of the values assigned to the present extreme wave-lengths. If they are, as we believe, to be trusted within the limits there given,

* On hitherto unrecognized wave-lengths. This Journal, August, 1885.

we have measured indications of lunar heat (and possibly of solar) greater than are shown on this drawing, and whose wave-lengths exceed one-fiftieth of a millimeter. It is not likely that the more refrangible of that extremely feeble heat, which we here particularly describe, is much less than 11^{μ}.

I think we may now feel justified in saying that we probably know some of the main facts about the solar spectrum, so far as terrestrial absorption is concerned. Broadly speaking, they are these:

Hardly one-fourth of the solar energy, as we receive it, is visible, at least without special precautions. Of the remaining three-fourths, far the larger portion of the heat actually received lies in the region above $2^{\mu}\cdot8$, which has already been delineated, but if it were not for terrestrial absorption, the heat in the region below it would be relatively so much greater, that it is probable that of the original solar energy, before absorption, *more* than three-fourths is invisible.

The effects of terrestrial absorption appear in the visible spectrum chiefly by means of the telluric Fraunhofer lines, so that our first impression on looking at it is that these lines only occasionally interrupt the play of light and color by which the solar energy makes itself known through the sense of vision. As we go down into these lower parts of the infra-red region, we find (directly contrary to the old belief) that, broadly speaking, the radiation apparently grows more and more transmissible by our atmosphere, and this because *the heat rays between the lines* grow more and more transmissible, while the lines themselves, though growing into broader bands of almost total absorption, have not yet extinguished the hot regions between them, so that, even taking regions of transmission and absorption together, on the whole here, i.e. above 3^{μ}, more of dark heat in proportion seems transmitted than of light heat. We may roughly illustrate* this portion of the sun's spectrum after absorption by saying that if it were visible, it would present almost the appearance of diffuse luminous bands on a dark field, somewhat like those seen in the spectra of stars of the fourth type. As we have observed that absorption seems to increase in the same direction in the sun's own atmosphere as in ours, it would be interesting to know if anything analogous exists in the absolute solar spectrum; i. e., before absorption in the sun's atmosphere, but this we are not as yet able to determine.

Since, in the part of the spectrum described here for the first time, the same process of aggregation into ever wider and

* Figure 3.

wider regions of absorption is continued till these intermediate regions of transmission disappear, the whole, to repeat an expression I have used in an earlier memoir, seems to become one continuous cold band, in which, however, we have found a little heat struggling through in the part beyond 11^{μ}. Briefly, then, we may say, that to an eye which could see the whole spectrum, visible and invisible, the luminous part being, as we know, interrupted by occasional dark lines, the lower part to 5^{μ} would appear to consist of alternate bright and dark bands, and the part below 5^{μ} be nearly dark, but with feeble "bright" bands at intervals. In conclusion, we may say that these new researches extend the known solar spectrum from three to much over the eighteen microns, shown on our plate, and while confirming the previously announced fact that the solar heat of the great wave-lengths which actually reach us is negligible in amount, show from the fact of the existence of any at all, that the anomaly of our being able to perceive lunar heat where we could not formerly detect solar, can be explained consistently with the possible existence of the latter of every wave-length before absorption.

These investigations into a problem of Solar Physics have also incidentally led us to the prospective means of solution of an important one in Meteorology, for they have opened to observation the hitherto unknown region of the spectrum, in which the nocturnal and diurnal radiations not only from the moon toward the earth, but from the soil of the earth toward space, are to be found and may be hereafter studied in detail.

Art. XLII.—*A brief history of Taconic ideas;* by James D. Dana.

As the Taconic controversy is now nearing its end, a brief review of the progress of ideas relating to the various sides of the subject from the time of the earliest discussions to the present will be found instructive.*

* A historical account of the Taconic, especially of the views of Taconic advocates, entitled "The Taconic System and its position in Stratigraphical Geology," by Mr. Jules Marcou, is contained in the Proceedings of the American Academy of Sciences, vol. xii, 1884, 1885, pages 174 to 256. It relates mainly to the "Upper" Taconic, and makes little mention of facts or observations of the thirty years past connected with the "Lower" Taconic rocks in the southern half of Vermont, Massachusetts with its typical Williamstown Taconic section, and in eastern New York from Rensselaer Co. southward; all which have a profound bearing on the question of age, and on the true relation of the "Upper" and "Lower" sections. No account is given of the Taconic system of 1842, in the detailed presentation of which Prof. Emmons states its fundamental and distinctive

1818 to 1828.—The name Taconic first came into topographical geology through Professor Chester Dewey, who made the earliest geological map of the region, observed the general arrangement and eastward pitch of the beds, and called the rocks in the style of the time, Transition rocks.*

Prof. Amos Eaton gave credit in 1820 to Prof. Dewey for the chief part of his knowledge of the Taconic rocks;† but, by 1828, this pioneer in American geology had made fifteen sections of the rocks from the Hudson River to the Taconic mountains, in order to ascertain, as he says, their conformability and true order of succession.‡

1836 to the close of 1841.—Prof. Emmons, whose department in the New York Geological Survey covered the northern and northeastern part of the State, and who was already acquainted with the adjoining region of Williamstown in Massachusetts, continued his survey into Williamstown. But in the New York Annual Reports no mention is made of the Taconic system either by him or by any other of the New York geologists. This is true even of the latest—the fifth—annual Report, that for 1840. Prof. Emmons, in his part of this Report, under the date of transmittal of Feb. 1, 1841, says on page 94:

"The Granular quartz of Bennington, which occurs also in Dutchess Co., N. Y., I believe to be Potsdam sandstone in a metamorphic form, and the granular limestone associated, to belong to the same geological epoch." I believe "that the rocks from Lake Champlain, along the eastern part of the counties of Washington, Rensselaer, Columbia, Dutchess, all of Putnam, Westchester, great part of Rockland and southeast part of Orange are metamorphic and intruded rocks, and I would suggest that all the rocks from the New York state line to the Connecticut valley are similar. The talcose and micaceous and talco-micaceous divisions of the Green Mountain range in Vermont, Massachusetts and Connecticut have a strong analogy to the metamorphic slates of the east part of Washington, Rensselaer and Columbia Counties, but are traversed by large granite veins and are interstratified with intrusive rocks which might be expected to produce a greater change in mineral constitution."

characteristics, and to which alone the discussions in 1842 to 1844 by Rogers, Mather, Hall and Hitchcock had reference. Mr. Marcou's own special Taconic investigations were made in northern Vermont and its vicinity, a region barely alluded to as Upper Taconic by Prof. Emmons.

* C. Dewey, this J., i, 337, 1819; ii, 246, 1820; viii, 1, 240, with the map, 1824.

† A. Eaton, Index to the Geology of the United States, 1820.

‡ A. Eaton, this J., xiv, 147, 1828, where he says: "I have traversed the Transition range from Massachusetts line to Hudson River in fifteen places, since the first part of my survey was published, for the purpose of ascertaining the true superposition of rocks in this most complicated and difficult geological theatre." Prof. G. H. Cook recently drew my attention to this statement of Prof. Eaton which I had previously overlooked.

As late, then, as February, 1841, there was no indication that the Taconic system had taken shape in the mind of Prof. Emmons, although pretty well stored with Taconic facts. In opposition to the ideas of the Taconic system of 1842, the quartzyte is spoken of as the "Potsdam sandstone" in a metamorphic state, and the associated granular limestone as of "the same geological epoch."

In 1842, the quarto Report on New York Geology by Prof. Emmons appeared, with its letter of transmittal dated January 1, 1842; and in this volume the account of the Taconic system as a new system of rocks in American geology covers pages 135 to 164, thirty quarto pages. The germinant period was, consequently, between February 1, 1841, and January 1, 1842.

Another fact brings us closer to the time of first announcement. The system became a subject of special discussion, as I am told by Prof. James Hall, at the meeting of the American Association of Geologists and Naturalists held early in April, 1841, at Philadelphia. This narrows down the germinating period to the two months between February 1 and April 10 of 1841.

Those who took a prominent part in this first discussion were Professors Henry D. Rogers, Edward Hitchcock, Wm. W. Mather, Mr. James Hall and Mr. Lardner Vanuxem. Prof. Rogers was interested in the subject because of his elaborate geological study of the Appalachian Mountain system on which he reported at length to the Association the following year; Prof. Hitchcock, because the heart of the Taconic region was within his own field of study—the state of Massachusetts,—his final report on which he already had in the press; Prof. Mather, because part of the Taconic rocks west of Massachusetts were very largely within his section of the survey of the State of New York; Prof. Hall, because of the bearing of the facts on the system of New York rocks. Prof. Vanuxem, also one of the New York State geologists, had under his charge only southern New York west of the Taconic area and had given the rocks no study.

Although we have no report of the discussions,* we learn from later publications that Professors Hitchcock, Rogers, Hall and Mather objected to the views of Prof. Emmons, and Mr. Vanuxem† favored them.

* The Proceedings of the meeting in this Journal, xli, 158, 1841, and in the Trans. Assoc. Am. Geol. and Nat., 1840–42, contain no allusion to the discussion, discussions being, as the Preface of the Transactions states, "imperfectly reported in these pages." The only fact of any Taconic interest mentioned in the Proceedings of the meeting for 1841 (Proc. Assoc., 1883, p. 16, and this J., xli, 163), is that of the occurrence of impressions of Annelids in the slate of Waterville, Me., by Prof. O. P. Hubbard—the fossils and slates being afterward (1844) claimed for the Taconic by Emmons. Prof. Wm. B. Rogers did not become a member until 1842.

† Mr. Vanuxem has a page on the subject in his N. Y. Geological Report, p. 22.

The comparison of views at the meeting resulted in inducing Prof. Rogers and Prof. Hall to take the field for the study of sections over the Taconic region. The season had just passed when Prof Rogers made a report on his results to the American Philosophical Society at Philadelphia,* sustaining the views which Hitchcock, Hall, Mather and himself had before favored, namely: that the rocks were Lower Silurian (as the term was then used) from the Potsdam upward, but much flexed and disguised by partial metamorphism. Prof. Emmons mentions in his Report of 1842, on p. 147, that "Professors Hitchcock and Rogers" were prominent objectors to his views. We learn that Prof. Mather's views were essentially those of Prof. Rogers from his New York Geological report published in 1843. In his Preface he gives an interesting account of the discussion. The Dr. Dana he refers to was Dr. Samuel L. Dana, of Lowell, Mass.

1842 to the close of 1844; Phase I.—Such was the state of opinion when Prof. Emmons's full report on the Taconic system was published in 1842.

The Taconic system of this report comprised the rocks from the Hoosic Mountains westward, passing over the Hoosic Valley, Saddle Mountain (which included Greylock), and also over the high ridge of granular quartz, Oak Hill, just north, the Williamstown plain, the Taconic Mountains next west on the Massachusetts boundary, and the eastern border of New York west of this boundary to the Hudson. Beginning on the east, the rocks were: (1) the "Stockbridge limestone," (2) the "Granular quartz" and the "magnesian slate" of Greylock, which are topographically north and south of one another, (3) the limestone of Williamstown plain, (4) the "magnesian slate" of the Taconic mountain, (5) the "sparry limestone" west of the latter, and farther west, (6) the "Taconic slate." The following, commencing at the bottom, is the chronological order according to Emmons, and in a parallel column, are given the true equivalents (the Roman numerals giving the order of age) as established by the latest investigations.

Taconic System of 1842.	*Equivalents.*
6. Stockbridge limestone.	II. Lower Silurian.
5. *a.* Magnesian slate of Greylock, perhaps a repetition of No. 3.	III. Hudson slate.
b. Granular quartz.	I. Cambrian.
4. Limestone.	II. Lower Silurian.
3. Magnesian slate of Taconic Mountain.	III. Hudson Slate.
2. Sparry limestone.	II. Lower Silurian.
1. Taconic slate.	III, I. Hudson slate and Cambrian.

* Proc. Amer. Phil. Soc., Jan., 1842.

The order of succession adopted by Emmons was the order of superposition, as he states, with arguments in its favor, on page 147 of his report, the idea of flexures being rejected. The granular quartz he says (p. 138) "lies between two masses of limestone,"—which is topographically a fact.

The idea of the pre-Potsdam age of the beds was based on the absence of fossils; on the difference in the kinds of rocks, and in their succession, from the lower rocks in the New York series; also on supposed unconformability, no special case however being mentioned. He says, with reference to the distinction in kinds of rocks (p. 139), "As a general rule, certain minerals are found in particular rocks; and may not a similar rule or law prevail where a system of rocks is concerned?"

Early in May of 1844, two years after the appearance of Prof. Emmons's Report and over half a year before his second presentation of the system, Professor H. D. Rogers brought the Taconic question into his Presidential address before the "Association of American Geologists and Naturalists," and reiterated his former conclusions.*

1844 to the close of 1849; Phase II.—In December, 1844, appeared as a pamphlet in 4to—the preface bearing the date December 2, 1844—Prof. Emmons's revision of the Taconic system, with additions and an extension of its limits; and in 1846, the same was published as a chapter in his N. Y. Report on Agriculture. The prominent changes are the following: (1) the system is, for the most part, turned the other side up, Rogers's views being adopted as to flexures and overthrust folds. (2) It is made in part fossiliferous, and the fossiliferous part is put at the top under the idea that the fossils proved it to be the newer part. (3) The granular quartz is placed at the bottom.

The order of the strata in the Report, and the equivalents, are as follows:

Taconic System of December, 1844.	*Equivalents.*
5. *a* Black slate (Bald Mt.)	I. Cambrian.
5. *b* Taconic slate.	III, I. Hudson slate and Cambrian.
4. Sparry limestone.	II. Lower Silurian.
3. Magnesian slate.	III. Hudson slates.
2. Stockbridge limestone.	II. Lower Silurian.
1. Granular quartz.	I. Cambrian.

* H. D. Rogers, this Journal. xlvii, 137, 247, 1844. The address is a discussion of geological views, and is of permanent interest. His remarks on the Taconic system occupy pages 150 to 153; and he ends them with the suggestion that the Taconic system, instead of belonging exclusively to the Champlain division, may "include also some of the sandy and slaty strata here spoken of as lying beneath the Potsdam sandstone," referring to his own observations in Virginia and East Tennessee.

The system thus had Cambrian at top and Cambrian at bottom. In the chapters on the granular quartz, doubts about its true position are admitted; but the decision as to its being the oldest in the series is not recalled.

The Report has an appendix on pages 109–112; and its closing sentences, which show wavering opinions, are important in the history. After saying that in this system of beds, made when the earth's condition earliest admitted of it, "we find the earliest beings which had life and vitality," he adds (p. 112): "We do not feel confident that it is in the earliest of these deposits that we have discovered fossils. Mr. James Hall, however, informs me that he found the *Scolithus*, a tubular polyparian, in the most easterly mass of the granular quartz. On visiting the place as described to me, I was not successful in my search for this fossil, but *at another locality I found what appears to be an orthoceratite.* The fossils, however, are more abundant in the newer rocks of this system; and they belong to beings of an extremely delicate construction, as the reader may see by reference to our description in another part of this report." The orthoceratite is not figured or again mentioned.

Prof. Emmons was led to make the "Black slate" of Bald Mountain either "a distinct rock, or merely the upper portion of the Taconic slate" by his discovery "during the early part of September," 1844, of a fossil "which resembles closely an Annelide," and the finding at the same place by Dr. Finch of two species of trilobites. The trilobites were named *Atops trilineatus* "evidently allied to *Triarthrus Beckii*, so abundant in the Utica slate" and *Elliptocephala asaphoides*, and figures are given on pages 64, 65. The "Taconic slate" of eastern New York, including the Hoosic slate, and occupying, as he says, "almost the whole of Columbia, Rensselaer and Washington Counties and reaching to St. Albans," was also put with the upper fossiliferous part of the system (pp. 67 to 71), because of the discovery of Annelid markings chiefly, *Nereites* and *Myrianites.*

These new New York fossils had claims to a place in the first volume of Prof. Hall's Paleontology of New York, which was published nearly two years later, the preface bearing the date September 1, 1846. The author made the *Atops* identical with *Triarthrus Beckii* and hence referred both trilobites, together with the slates, to the Hudson river group; and the Elliptocephalus was referred to the genus *Olenus.* In the same month, the question of identity was discussed at the meeting of the Association of Geologists and Naturalists and a committee of investigation appointed for its consideration

and at the following meeting in 1847, Mr. S. S. Haldeman, the chairman of the committee, made an adverse report.* A reply from Mr. Hall appeared in this Journal in 1848.†

The discussion was continued at the first meeting of the American Association for the Advancement of Science (an expansion of the Association of American Geologists and Naturalists), in 1848, when Prof. Emmons read a paper entitled "On the identity of the *Atops trilineatus* and the *Triarthrus Beckii*, with remarks upon the *Elliptocephalus asaphoides*," in which he gives a full comparison of characters and also points out the differences between the latter species and either of the allied genera *Olenus* and *Paradoxides*.‡

The following year, 1849, a new advocate of the views of Rogers and Mather, in opposition to Emmons, appeared, in Mr. T. S. Hunt, then of the Geological Survey of Canada, who presented that year to the American Association for the Advancement of Science, at its second meeting in Cambridge, an abstract of the Geological Report of Canada for the year 1847–8.§ But it does not appear that either Mr. Hunt, or any one connected with the Canadian survey, had made the Taconic region a subject of investigation.

1855 to 1859; Phase III.—In the year 1855, Prof. Emmons made, in his new volume entitled "American Geology," his *third* presentation of the Taconic System.‖ The chief changes introduced are the following: (1) The fossiliferous portion of the system is now called the *Upper Taconic*, and the rest the *Lower Taconic*; (2) the Sparry and Stockbridge limestones are brought together as one formation; (3) the synclinal character of Greylock is first recognized and figured; and (4) extensions of the system to new localities are mentioned.

The order of succession in this third phase of the system and the true equivalents are as follows:

Taconic System in 1855.		*Equivalents.*
Upper Taconic.	2. Black slate of Bald Mountain.	I. Cambrian.
	1. Taconic slate.	III, I. Hudson slates and Cambrian.
Lower Taconic.	3. Magnesia slate.	III. Hudson slates.
	2. Stockbridge limestone.	II. Lower Silurian.
	1. Granular quartz.	I. Cambrian.

* S. S. Haldeman, this Journal, II, v, 117, 1848. At the same meeting, in 1847, Prof. C. B. Adams, of the Vermont Geological Survey, read a brief note on the Taconic rocks of Addison County, Vt., in opposition to the system.

† James Hall, this Journal, II, v, 322, 1848.

‡ E. Emmons, Proc. Amer. Assoc. for 1848, vol. i, p. 16.

§ T. S. Hunt, Proc. Amer. Assoc. for 1849, vol. ii, p. 325, and this Journal, II, ix, 12, 1850.

‖ Occupies pages 1 to 122 of Part II of the American Geology, 8vo, Albany, 1855.

This system of 1855, like that of 1844, has a top and bottom of Cambrian rocks. The succession of rocks in the "Lower" Taconic—which, it should be remembered, were the only rocks in the system when Rogers wrote in 1841 and 1844 and Mather in 1843—coincides with the views early set forth by Rogers, and with the order established by the most recent discoveries of fossils.

Professor Emmons, on page 70 of the American Geology, earnestly sustains the *azoic* character of the "*Lower*" Taconic, and particularly that of the slates of Saddle Mountain or Greylock. But the sentences about the occurrence of fossils in other parts of the "Lower" Taconic are left ambiguous. Speaking of the Taconic system as a whole on the closing page (p. 122) he says: (3) "It is a vital system, having been deposited during the period when organisms existed." (6) It "carries us back many stages farther in time when life gave vitality to its waters than the Silurian." He also says: "(1) Its series, divided into groups, are physically unlike the Lower Silurian series." "(2) It supports unconformably at numerous places the Lower Silurian rocks." Again on page 49: This group, "the 'Lower' Taconic, is mostly anterior to the Organic period." No locality of Taconic trilobites is mentioned in the chapters except that of Bald Mountain in Rensselaer Co., N. Y., and one of much interest in Augusta Co., Virginia, which had afforded Professor Emmons the small species he named *Microdiscus quadricostatus*.

In 1854 or 1855 new Trilobites, related to those of Bald Mountain, were found in the Black Slates of West Georgia, Vermont, within the range of beds referred to the "Upper" Taconic. Passing into the hands of Mr. Zadock Thompson, who had been assistant in the Geological Survey of the State under Professor C. B. Adams, the specimens were sent to Professor Hall, and in 1859, they were figured and described by him as "Trilobites of the shales of the Hudson River Group," under the names *Olenus Thompsoni*, *O. Vermontana* and *Peltura holopyga*, and the beds were thus made equivalents of the Bald Mountain slates.* Although these fossils

*J. Hall, Twelfth Annual Rep. N. Y. State Cab. Nat. Hist., pp. 59–62, 1859. Also Vol. III, N. Y. Paleontology, 1859, p. 325; Rep. Geol. Vermont, p. 367, where the two species of Olenus are *united* under the name *Barrandia Vermontana*. In Vol. III of the Paleontology, Professor Hall says, on page 94, "In the western flank of the Green Mountain range, the great variety of schists, designated as talcous, mica, gneissoid mica, hornblende and calcareous mica slates are all results of metamorphism of Silurian strata;" and on p. 83: "It is now many years since the belt of the country was regarded as one great Primary mass. Later observers began to yield a little and contented themselves with a Primary axis; and now we have the evidence, derived from fossils occurring at intervals over much of the area between the Hudson and the Connecticut rivers, as well as

were not formally claimed as Upper Taconic by Professor Emmons, they have passed as such. His Manual of Geology, the preface of which bears the date May 1, 1859, contains a good figure of a large trilobite under the name *Paradoxides brachycephalus*,* which (as first suggested by Professor C. H. Hitchcock in 1861† and is recently recognized by Mr. Walcott)‡ is identical with Hall's *Olenus Thompsoni*; and it was evidently so named before the publication of Prof. Hall's paper, though whether *published* before is not certain. Unfortunately, Professor Emmons failed to mention the locality of his specimen. On page 87, he makes the following judicious remark: "According to Barrande, the *Paradoxides* and

from the geological structure of the country, that these rocks all consist of strata lying between the base of the Silurian and the beginning of the Coal-measures."

On page 94, in a note, occurs the statement—of historical interest and therefore here cited—that staurolite and some other minerals "mark with the same unerring certainty the geological relations of this rock [a mica schist passing through central New England] as the presence of *Pentamerus oblongus*, *P. galeatus*, *Spirifer Niagarensis*, *S. macropleura*, and their respectively associated fossils, do the relations of the several rocks in which they occur." It was a valuable suggestion at the time, but one that the establishment of the facts just cited from p. 83 has now set aside.

In 1857, two years before the publication of Vol. III of the N. Y. Paleontology, cited from above, Professor Hall delivered an address before the American Association at Montreal. The writer was absent and never learned anything about its contents; it was never published. In 1882, only six years since, appeared a pamphlet, of forty pages, entitled "Contributions to the Geological History of the American Continent. The Address of the retiring President delivered before the first Montreal Meeting of the American Association for the Advancement of Science, August, 1857, by JAMES HALL." A note to the title is appended in which the author says: "The original manuscript of his Address" "has been copied without any supervision by him or any changes suggested by him." This publication of the Address cannot claim to have historical value and hence demands no notice here; for it came out *twenty-five years after date*. It has no scientific importance; for the subjects presented are much more fully and more satisfactorily discussed in the 96 quarto pages of the valuable Introduction to Vol. III, above mentioned, all of which is Professor Hall's, and besides is two years later than the Address. In the Appendix to this pamphlet on p. 68, it is stated that "the Address has been facetiously criticised as proposing a system of mountain-making with the [origin of the] mountains left out" Accordingly, the *Address*, although it had never been published, had on one subject been "facetiously criticised." The critical remark referred to occurred in volume xlii (1866, p. 210) of this Journal, in a note on views published by Professor Hall *in his Volume III*, as is stated in the note, and had no reference to the unpublished and wholly unknown Address. Some officious friend has made a slip here; Professor Hall could not have so forgotten himself. The pamphlet closes, following this, with two pages of "Notes on Professor James Hall's Address by T. Sterry Hunt."

* Manual of Geology by E. Emmons, 290 pp. 8vo. Philadelphia, 1860; see p. 88. Also C. D. Walcott on Cambrian Faunas, 2d paper, Bull. No. 30, U. S. G. S., 1886, p. 167. The name *Paradoxides asaphoides* is given by Professor Emmons for the figure on page 87, as if his first intention was to have inserted his old figure of *Elliptocephalus asaphoides*, but afterward decided to insert a figure of the new species. The name *P. brachycephalus* is changed to *P. macrocephalus* in a second issue of the Manual (1860), both under the cut on page 88 and in a note to page 280, and the corrected name is cited by Mr. Walcott.

† Rep. Geol. Vermont, p. 367.

‡ Bull. U. S. G. S., No. 30.

Olenus belong to his Primordial zone or are Sub-silurian in Bohemia. In this respect our Paradoxides are also Sub-silurian: and hence it has been shown that the Primordial zone in Bohemia is in coördination with the upper series of the Taconic rocks." Professor Emmons's letters to Mr. Marcou written in 1860 and published by the latter in the Proceedings of the American Academy for 1884, show that he meant here to emphasize "Upper" Primordial; for he protests that only a small part of his system is coincident with Barrande's Primordial.

1860 to 1863.—The years 1860 to 1863 were epochal in Taconic History. Great light was let in upon the system by letters of August, 1860, from Barrande, the eminent paleontologist of the Silurian of Bohemia, addressed to Professor Bronn of Heidelberg and Mr. Marcou of Cambridge, Mass., and also from a memoir read by him before the Geological Society of France. Having before him the figures and descriptions of the Georgia trilobites, referred to above, received from Mr. Billings, he pronounced them unquestionably Primordial, thus confirming the decision of Professor Emmons just mentioned.

But Barrande, adopting in his Memoir in full the views of Emmons on the Taconic system, and regarding the Primordial fossils as really characteristic of a great Taconic system of rocks extending far below the Olenus or Paradoxides zone, speaks of the Taconic as the American Primordial—his own system under unusual development—a view not satisfactory to Professor Emmons, for he had in contemplation for his Lower Taconic much greater depths, something like the unsounded Huronian, equivalency with which he thought he could make out.* And thus confusion was introduced by Barrande along with the

* Barrande's letters are addressed—Paris, July 16, 1860, to Professor Bronn of Heidelberg, and August 14th, 1860, to M. J. Marcou. They were read before the Boston Soc. Nat. Hist. in October, 1860, and are published in the Proceedings, vol. vii, 371; also in this Journal, II, xxxi, 210, 1861, with an omission of Mr. Marcou's name because of its unmentioned omission on the part of the sender (from Canada) of the communication; also in the Geol. Rep. Vermont (with the same omission) p. 377; and also, with other letters, in Mr. Marcou's paper in the Proc. Amer. Acad., vol. xii; see page 411. In this Journal and in the Vermont Report the letters are followed by letters to M. Barrande from Logan and from Hall; also in the Boston Proceedings, vol. vii, and also vol. viii, 239, by remarks of Mr. Marcou, giving his view of the bearings of the facts on the Taconic system of Emmons, with some additional facts. Barrande's Memoir referred to above is entitled, "Documents anciens et nouveaux sur la Fauna primordiale et le Système Taconique en Amérique," and was presented to the Geological Society of France, Nov., 1860, and Feb., 1861.

Barrande's letters appeared also in the Canada Nat. and Geol. for 1861. The facts show that some person connected with the Geological Survey of Canada is accountable for the "omission" above referred to. Mr. Marcou's paper of 1884 gave the editors of this Journal their first knowledge of it.

light. It would not have been so, we are sure from his careful Bohemian work, had he been within reach of the stratigraphical problem, for he would have withheld his general conclusion until he had investigated the region of the Taconic rocks.

Trouble came in 1860 again through the recognition by Logan of the Quebec Group in Canada—based on fossils from the vicinity of Quebec that corresponded in age apparently to the combined Calciferous and Chazy Groups.* For this step was followed by Logan's announcing, without previously making a careful stratigraphical study of the region, that the Taconic slates and limestone were, for the most part at least, of the Quebec Group.

Light came in again through the Vermont Geological Survey;† (1) by the discovery of fossils of undoubted Silurian age at several localities in the Stockbridge (Eolian) limestone of Vermont, the Report says (p. 421) Silurian, Devonian, and possibly Carboniferous); (2) by the exhibition of the topographical relations of the rocks on the colored geological map of Vermont; and (3) through the stratigraphical sections across the limestone and slates, making in Mt. Anthony, Mt. Equinox, Spruce Peak, Mt. Eolus or Dorset and Danby Mountain the slates to lie in synclines with the limestone underneath, precisely as had been proved for Greylock by Emmons. Here at one stroke, Emmons was sustained in his stratigraphy as regards his "Lower" Taconic, and shown to be probably wrong in his conclusion as to the pre-Potsdam age of the limestone, and part at least of the slates. No definite conclusion was reached by the survey as to the age of the quartzyte, opinion varying between Potsdam and Medina.‡

* Sir Wm. Logan, Remarks on the Fauna of the Quebec Group of Rocks and the Primordial Zone of Canada, Jan., 1861, Letter to Barrande, this Journal, II, xxxi, 216, 1861; Considerations relating to the Quebec Group, Can. Nat. and Geol., p. 199, May, 1861.

Mr. Billings first observed the peculiar features of the fossils of the so-called Quebec Group in May, 1860 (Geol. Rep. Can., 1863, p. viii), and the Canadian Nat. and Geol. for 1860 contains his earliest descriptions of the fossils, afterward given in full, with an account of the rocks by Logan in the Can. Geol. Rep. for 1863, and more completely in Billings's Palæozoic fossils, vol. 1.

† Rep. Geol. Vermont by E. Hitchcock, E. Hitchcock, Jr., A. D. Hager and C H. Hitchcock, 1861. In a note published in the Proceedings of the Boston N. H. Soc., vol. xxiv, 1888, Prof. C. H. Hitchcock states that the printing of the Report commenced in 1861, and was all completed that year, excepting the Appendix on "Lower Silurian fossils" by E. Billings.

‡ Ibid., pp. 356, 500. On the latter page, the opinion is cited from Professor Hall, based on the discovery of a species of Lingula, that the quartzyte is "of the age of the Clinton Group or of the Medina Group," Upper Silurian formations. Bearing on the history we find in the Proc. Boston Soc. N. H., vii, 237, 1860, a note by Professor W. B. Rogers, in which, in view of the reference to the Medina group, he cites approvingly, from a manuscript paper of his written in 1851, paragraphs sustaining the Medina age of the Vermont Quartzyte and Red Sandrock. The latter rock Emmons never included in the Taconic.

But along with the light from Vermont, doubts entered through the reference of some of the fossils of the limestone to the Upper Silurian and perhaps Devonian, and the use made of the few fossils of the Quartzyte. The facts were partly righted in 1862 by Mr. Billings, the paleontologist of Canada, who reviewed the Vermont Report in this Journal, and claimed that "the evidence of the fossils furnishes no reasonable ground for placing the formation above the Lower Silurian."*

Accepting the stratigraphical sections in the Vermont Report as teaching what they appear to teach, and recognizing the Lower Silurian age of the fossils from the limestone, and accepting also Barrande's confirmation of Emmons's decision as to the Primordial relations of the "Black slate" trilobites, the general bearing of the facts made known, during this epoch of progress and drawbacks, could hardly be mistaken.

At this time the first edition of the writer's Manual of Geology† was published. The preface bears the date of the close of the printing, November 1, 1862. The Potsdam period in American Geology had already become expanded into the Primordial by the discovery, six years before, near Boston, of specimens of *Paradoxides Harlani*‡ and by facts received from abroad; and it is designated in the work (pp. 169, 171) the "POTSDAM OR PRIMORDIAL PERIOD," and made the equivalent of the era of the Paradoxides and other Primordial beds of Scandinavia and Bohemia, as well as of that of the Lingula Flags and underlying Cambrian of Great Britain. Moreover, *Paradoxides*, *Olenus*, and other Lower Cambrian genera are cited, and *P. Harlani* appears among the figured species. Barrande's determinations of the Georgia Slate Trilobites, making them and the beds containing them Primordial, are recognized by mentioning the beds and fossils among the facts of the "Potsdam or Primordial Period"—conforming in this to the decision of Emmons as well as Barrande.

The Vermont discoveries of fossils in the Eolian limestone had proved that the limestone and the overlying slates were

* E. Billings, this J., II., xxxiii, 416, 1862.

In 1870 the chief divisions in the geology of Vermont were briefly stated by Prof. C. H. Hitchcock in a folio of six pages bearing the date of March 1st. His further study of the State, in connection with the work of the Canadian Survey, had led him to refer at this time the Eolian or Stockbridge limestone and associated slates to the Quebec group, and the Quartzyte, Red Sandrock and the Georgia slates and Black slate to the Potsdam or Primordial, the last-mentioned the oldest.

† Manual of Geology by James D. Dana, 798 pp. 8vo, illustrated by a chart of the world and over 2000 figures. Philadelphia, 1863.

‡ W. B. Rogers, this J., II, xxii, 296, 1856, from a letter to J. D. Dana of August 13. Prof. Rogers compares the fossil with the *P. spinosus* of Barrande, and identifies it with the *P. Harlani* of Green. Mr. Green's cast of a specimen of unknown locality, had been widely distributed, and had reached Barrande. He also shows by Green's description of the rock, that his specimen was probably of the same locality.

later rocks than the Primordial, at least as late as Lower Silurian; and hence the term Taconic could not have been substituted for Primordial, as only a small part of the system was Primordial: the name belonged by first right to the original Taconic of 1842. The Primordial addition to the top of the Taconic column made by Emmons in 1844 was rectified by simply recording the facts in their proper places. The Eolian or Stockbridge limestone and other "Lower" Taconic rocks are mentioned in the Manual under the Calciferous (pp. 175, 176) in connection with remarks on the Quebec group; but it is added that "fossils probably of the Trenton period occur in the Vermont limestone"; and on p. 391, evidence in favor of a Trenton rather than a Calciferous or Quebec age is presented, based on the facts from the Vermont Geological Survey and the remarks by Billings.

By the close of the year 1862, therefore, the Black slates of the "Upper" Taconic had reached their right place in a Geological Manual. There remained however to be yet made out their particular horizon in the Cambrian, the particular periods of the Lower Silurian represented in the Stockbridge limestone, and the age of the quartzyte.

1865 to 1872.—In May, 1870, Rev. A. Wing, of Vermont, collected fossils from the limestone at West Rutland "not 100 yards from an abandoned marble quarry," which were sent a year later (June, 1871), to Mr. E. Billings, of Montreal, who reported upon them in this Journal for 1872, pronouncing them probably Chazy.* Mr. Wing had been exploring since 1865, in order to "ascertain if possible the geological age of the limestones, slates and quartzite," and relied on Mr. Billings for the determination of his fossils.† In 1867, Mr. Billings identified for him *Asaphus canalis*, two or three species of *Bathyurus*, *Maclurea matutina*, from the limestone in Cornwall, Vt., and made the species *Calciferous*. The same year he found the Trenton fossil *Trinucleus concentricus* in place "in great abundance" in Sudbury; also about this time or between it and 1872, he found "*Bathyurus Saffordi*, a Quebec Group trilobite" in East Cornwall; *Bathyurus extans*, a Birdseye species, *Columnaria alveolata*, a Black River species, and the *Trinucleus*, east of Shoreham; and confirmatory species as to the Calciferous as well as the later periods from other localities.

By 1872,‡ Mr. Wing had established one of the points he had in view, that the limestone was not, as Logan had held, of the Quebec group, or of Calciferous and Chazy only, but embraced the Trenton also, and apparently all the Lower Silurian forma-

* E. Billings, this J., III, iv, 133, 1872.
† A. Wing, this J., II, xiii, 332, 405, 1877.
‡ This J., III, iv, 1872; and for his conclusions, p. 414.

tions from the Calciferous to the Trenton; and, consequently, he had made it certain that whatever slates were really overlying were of Utica or Hudson age.

In 1869, an article by Prof. J. B. Perry appeared in this Journal, sustaining, by the results of his observations in Vermont, the Taconic system as presented by Emmons. As its principal stratigraphic points have now been disproved by the discovery of fossils, and evidence of the existence of faults and flexures which he misunderstood, it need not be noticed here.

1872 to 1886.—In 1871 the writer entered the field, believing that the Chazy fossils of West Rutland—the only part of Wing's discoveries then published—and the earlier discoveries of the Vermont Survey, made the region a good and certain base for a determination of the age of the Massachusetts and more southern portions of the Taconic rocks, as well as of the Vermont portion, and, thence, of the age of the schists throughout the Taconic Range. My purpose was (1) to prove the continuity from north to south of the three *associated* Taconic formations, the quartzyte, the limestone and the slates or schists; also (2) to work out the system of flexures; (3) to ascertain whether the Taconic Mountains were generally or not of synclinal structure, as they were made by Rogers, Mather and Hall, and in 1864 by Logan;* (4) to settle the question as to continuity from east to west of the limestone of the different north-and-south belts; (5) to apply the evidence from fossils, making them the sole basis for fixing the age of the beds; and finally (6), to use the evidence of the age, thus obtained, for the determination of the age of the hydromica schists, chloritic schists, garnetiferous and staurolitic schists, and other rocks of the Taconic Mountains, and thus test the value of, or give greater precision to, the assumed "lithological canon" first propounded by Prof. Emmons (p. 414). My work was continued in Western New England and Eastern New York at intervals from 1871 to the close of the season of 1886. In 1876 I accompanied Mr. Wing on a Vermont excursion, visiting besides other places, the West Rutland region of fossils in the limestone; a locality of small Orthocerata, apparently Calciferous, in the limestone two miles north of Middlebury, which Mr. Wing figured;† and the region of the Snake Mountain overthrust fault which he well understood.‡

By 1878, the problem began to receive new light from the discoveries of fossils outside of Vermont. In 1878, Mr. T. N. Dale announced Brachiopods of the Hudson Group in the Poughkeepsie Taconic slate.§ In 1878, Professor Wm. B. Dwight

* This J., II, xxxix, 96, 1865.
† A. Wing, this J., III, xiii, 406, 1877, where the Orthocerata are figured.
‡ Ibid., p. 413.
§ Dale, this J., III, xvii, 57, 1879.

began his numerous discoveries of Trenton and Calciferous fossils in the belts of "Sparry limestone" of Dutchess Co., N. Y., which he has continued to 1888;* and in 1885 and 1886 made other discoveries in the "Sparry limestone"—strictly the southern part of the Eolian—in Canaan, Columbia Co., N. Y., just west of the Taconic Range.† Thus the evidence of the Lower Silurian age of the limestone and slate went on accumulating. Further, both Hudson River and pre-Potsdam Cambrian fossils were reported by Mr. S. W. Ford from the east border of the Hudson near Schodack landing,‡ and Upper Cambrian by Professor Dwight near Poughkeepsie,§ both being cases of the uplift of Cambrian beds along a fault. Professor Dwight found the Hudson shales to be the prevailing rock in Dutchess County; also that it was intersected by numerous faults: Potsdam occurring faulted against Trenton, against Calciferous and against Hudson shales; and the Calciferous against Trenton and Hudson shales. Again, in 1886, Mr. I. P. Bishop, of Chatham, Columbia Co., N. Y., eight miles southwest of Canaan, announced‖ the occurrence of Hudson group graptolitic schists and fossiliferous Trenton limestone at that place, and the continuation of the beds northward to the borders of Rensselaer Co., N. Y., and south to Ghent—facts that bore on the age of the "Taconic slate" of Emmons not only for Columbia County but also for the region north.

My papers appeared in this Journal in 1872, 1873, 1877, 1879, 1880, 1884, and finally in 1885 and 1886, the series was continued, with new results, and the completion of a geological map of the limestone areas of the Taconic region east and west of the Taconic Range from Northern Bennington in Vermont to the southern limit of Canaan and Salisbury, Conn. It is not necessary to mention here conclusions. I was slow in reaching any positive conclusion about the age of the quartzyte because of the non-discovery of fossils, which I made the only reliable evidence of age. But in 1884 discovering chondroditic limestone in eastern Berkshire as evidence of the presence of Archæan, I made out an eastern quartzyte as Potsdam or Cambrian, leaving the quartzyte that alternates with the schists and limestone in the center of the Taconic limestone region, still in doubt. But the evidence was not sufficient to prove that there was a continuous belt of Archæan along eastern Berkshire and the Green Mountain Range to the north, so that

* W. B. Dwight, this J., III, xvii, 389, 1879, xix, 50, 451, 1880, xxi, 78, 1881, xxvii, 249, 1884.
† W. B. Dwight, this J., xxxi, 248, 1886.
‡ S. W. Ford, this J., III, xxviii, 35, 206, 242, 1884, xxix, 16, 1885.
§ W. B. Dwight, this J., III, xxxi, 125, 1886, xxxiv, 27, 1887.
‖ I P. Bishop, this J., xxxii, 438, 1886.

part of the mica schist and gneiss remained in doubt, as, for example, that of Hoosic Mountain east of North Adams, and that of Mt. Mansfield in the Green Mountains,* not knowing whether to pronounce them of the age of the Taconic Greylock schists which they closely resemble, or of that of the schists in the Quartzyte formation, or of Archæan age—thinking the last the least probable.†

In 1884 Professor C. H. Hitchcock published an account of new sections made by him across Vermont and New Hampshire, sustaining essentially his former conclusions as to the Lower Silurian age of the limestone and slates, making the Eolian limestone Lower Silurian.‡

Other papers, besides those that have been mentioned, appeared during the thirty years from 1855 to 1886, but none of importance that were the direct result of investigation of the Taconic region apart from what appeared on Northern Vermont and Canada. Articles on the Taconic system by Dr. T. Sterry Hunt have come out from time to time since his first in 1849 giving the views he had adopted ; views that were strongly opposed to Professor Emmons for nearly thirty years, and for the last ten, from 1878 to 1888, as strongly or a little more so, in favor of the Taconic system and in contest with the facts that were fast accumulating against it. As the arguments and conclusions presented were at no time based on his own investigations in the Taconic region there has been no occasion to cite from his papers.

1887, 1888.—In 1886 Mr. Charles D. Walcott, the excellent paleontologist of the United States Geological Survey, commenced the study of the Taconic slates, limestone and quartzyte of Northern and Southern Vermont and the adjoining counties in New York ; and in 1887, he continued his work southward into Williamstown in Massachusetts and to Berlin, southwest of Williamstown, in eastern New York. He added largely to the number of known Cambrian fossils of the Georgia region in Vermont and of Washington County in New York besides studying the stratigraphy ; made many new discoveries of fossils in southern Vermont, finding in the

* Mt. Mansfield is the only peak of the Green Mountains which I have ascended.

† The quartzyte regions of (1) Washington, Mass., southeastern Pittsfield and eastern Lenox, (2) the eastern border of Tyringham, Mass., (3) the southern border of Canaan, Ct., adjoining Cornwall, and (4) the northern border of high eastern Sharon, Ct., near Salisbury, where there are quarries, are among the best localities for the study of transitions in the quartzyte toward gneiss ; they were to have been my field of work in 1887, and failed to be so because of my sudden move to the Hawaiian Islands.

‡ C. H. Hitchcock, 34 pp. 8vo, with 2 plates, Concord, N. H., 1884. Bull. Amer. Mus. N. Hist., i, no. 5, p. 155, 1884 ; a note to the title says, "This article was prepared in 1882."

Stockbridge (Eolian) limestone Trenton fossils within half a mile of the Massachusetts line in Pownal; other Lower Silurian fossils on both sides of Mt. Anthony, three miles south of Bennington, a Trenton crinoid included; Trenton fossils in Williamstown, at the Hopper, at the west foot of Greylock and others in Berlin south of South Berlin; and at Hoosic Falls in Rensselaer Co., New York, west of Bennington, Trenton fossils again.*—The results warrant full confidence, he says, in the Calciferous-Trenton age of the limestone. Further, in the slates at Hoosic he obtained Graptolites, as had long before been found, of Hudson age. In the study of the quartzyte of Vermont, specimens in the Amherst cabinet (Amherst, Mass.) afforded him the species *Nothozoe Vermontana*, *Olenellus Thompsoni* and *Hyolithes communis;* the quartzyte mountain, two miles east of Bennington, Vt., gave him specimens of *Nothozoe*, *Olenellus* and *Hyolithes*, and the quartzyte of the west summit of Clarksburg Mountain or Oak Hill, on the borders of Williamstown, an *Olenellus*. These discoveries were preceded in 1886 by finding, along with Professor Dwight, *Hyolithellus micans* in the limestone resting on the quartzyte of Stissing Mountain in Dutchess Co., N. Y. (the quartzyte referred to by Professor Emmons), and heads of *Olenellus Thompsoni* at the same place in the quartzyte itself.

The colored map accompanying his paper in volume xxxv (1888) of this Journal has the above mentioned localities of fossils indicated, and also those of Cambrian age within the area of the Taconic slates over eastern New York and the borders of Vermont. The fossils are positive evidence of the age of the slates at the localities where they occur. But how far the slates away from the localities are Cambrian, or how far they are, instead, of the Hudson group, with faults here and there bringing up Cambrian, in Eastern New York, as in Dutchess County, remains yet to be ascertained. The doubt does not affect the general conclusion from the facts. Further, Mr. Walcott made out that the quartzyte formation, and the Bald Mountain and Georgia slates were alike in belonging distinctively to the Olenellus section of the Cambrian.

These discoveries of Mr. Walcott afford the first demonstration of the age of the quartzyte, and give new precision to our knowledge of the age of the Georgia, Bald Mountain and associated slates. Besides this, they give full completeness to the proof, that had been for years accumulating, of the Lower Silurian age of the Taconic limestone. They show, moreover, that the Primordial beds constituting Emmons's "Upper" Taconic, on account of which the terms Primordial and Taconic have by some been thought to be rightful synonyms, are

* C. D. Walcott, this Journal, III, xxxiv, 187, 1887, xxxv, 229, 307, 394, 1888.

only outcrops of the Cambrian formation of the "Lower" Taconic; that the "Lower" Taconic includes the "Upper" and is therefore all there is of Taconic.

It is thus finally made positive that the Taconic system is not a pre-Silurian system, and that the claiming for its equivalency with the Huronian was but a leap in the dark. It is manifest, in fact, that "Taconic system" is only a synonym of the older term "Lower Silurian," as this term was used by geologists generally, twenty, thirty and forty years since, and by many writers till a much later date.

It is almost fifty years since the Taconic system made its abrupt entrance into geological science. Notwithstanding some good points, it has been, through its greater errors, long a hindrance to progress here and abroad. It has also been a promoter of investigations of wide bearing and influence. But, whether the evil or the good has predominated, we may now hope, while heartily honoring Professor Emmons for his earnest geological labors and his discoveries, that Taconic ideas may be allowed to be and remain part of the past.

1841-1888.

ART. XLIII.—*Certain Generic Electrical Relations of the Alloys of Platinum;** by C. BARUS.

IF the specific electrical resistance (s) of a metal be expressed by $s=f(\chi, t)$, where t is the symbol of temperature and χ a variable parameter, then the data of the present paper may be said to furnish evidence of an inherent physical relation between $f(\chi,0)$ and $f'(\chi,0)$—i. e. the zero values of s and its first derived function with respect to t,—provided the largest admissible value of χ be small in comparison with its maximum value. Usually variations of χ are produced by changing the qualities of the originally pure metal by small quantities of some foreign ingredient, metallic or not. With the understanding thus laid down, $f'(\chi,0)/f(\chi,0)$ is the succinct interpretation of what is ordinarily called temperature-coefficient, and which in the present paper will often be denoted by α. Conformably with the notation indicated $f(0,0)$ and $f'(0,0)$ are the constants of the unalloyed metal. When this is not thus explicitly stated, I will for the sake of brevity use $f(0)$ and $f'(0)$ in place of $f(\chi,0)$ and $f'(\chi,0)$, respectively.

* This paper indicates the chief result of the third chapter of the Bulletin on the measurement of high temperatures, to which reference has already been made. (See this Journal, xxxv, p. 407, 1888.)

The expression for electrical conductivity is here $1/f(\chi, t)$, to be abbreviated λ. If $s=s_0(1+at+\beta t^2+\ldots.)$, it follows that $\lambda=\lambda_0(1-at+(a^2-\beta)t^2-\ldots.)$; and hence the temperature coefficients, taken in the sense just defined, are numerically identical, no matter whether reference is made to s or to λ.

The alloys of which the present paper treats are all characterized by high melting points, and by *non-crystalline* structure. Alloys fusing below red heat have not been systematically investigated, or lead to involved results. The case of amalgams* is complicated by changes of the physical state of aggregation. Strictly speaking investigations like the present hold only for those alloys for which data are in hand. Cf. § 3.

2. The advantages of selecting platinum-alloys for the investigation in question are manifold. Melted platinum appears to be a universal solvent of metals, and hence the variety of bimetallic platinum alloys, easily producible, is very great. Again one of the remarkable electrical properties of platinum is the tendency to form alloys of phenomenally high specific resistance; and quite within the limits stated in §1, an electrical effect of alloying amounting to as much as 500 per cent of the specific resistance of platinum, is no unusual occurrence. Finally platinum alloys have not yet been systematically studied. The present contribution is therefore new.

In the case of steel to which I shall allude in passing, variations of resistance allied in character to those here discussed may be produced by changes of temper. The range of electrical variation here is also very large, amounting to more than 300 per cent of the resistance of soft steel.

Phenomena extending over such an enormous range, and which admit of exact measurement throughout the whole interval of variation, deserve most careful scrutiny and comparison even in their approximate relations. But there is further evidence in hand of the importance of which, when my work was in progress, I was quite unaware. I shall endeavor to digest it in the next paragraph.

3. A research into the relations of electrical conductivity and temperature makes up a part of the labors of Matthiessen. In addition to his well-known results for pure metals, Matthiessen† and his friends investigate the electrics of alloys of PbAg, SnAu, SnCu, SnAg, ZnCu, AuCu, AuAg, PtAg, PdAg, CuAg, FeAu, FeCu, PCu, AsCu, and some other metals. Unfortunately not all of these alloys are available for the present discussion, as Matthiessen's purpose seems rather to have been the exploitation of a great number of series of groups of alloys. On the other hand it is my purpose to examine the

*Cf. C. L. Weber: Wied. Ann., xxiii, p. 447, 1884; ibid., xxxi, p. 243, 1887. Battelli: Beiblätter, xii, p. 587, 1888.

†Matthiessen and Vogt: Pogg. Ann., cxxii, p. 19, 1864.

electrical behavior of as many alloys as possible of one given group. On perusing Matthiessen and Vogt's results, it appears that lead alloys,* tin alloys and iron alloys will have to be excluded from the present consideration, inasmuch as the data are either insufficient in number, or lie too far apart from each other and from the extremes of this series, or because of mechanical difficulties encountered in making the alloys and shaping the wires. There remain a very full series of copper alloys, viz: CuSn, CuZn, CuFe, CuP, CuAs; a series of silver alloys, viz: AgAu, AgPt, AgPd, AgCu; and a few gold alloys, viz: AuCu, AuAg. In view of the importance of these data I have computed the following tabular statement of Matthiessen's results, re-arranging the data in a way which for my special purposes is expedient. I have also added Matthiessen's† results for pure, soft metals. In table I, λ'_0 denotes the conductivity in Matthiessen's standards (Ag=100), α the temperature coefficient of the alloy, of which the composition is given on the same horizontal row. I have rounded off Matthiessen's long numbers, because the arbitrary errors introduced during the mechanical preparation of the alloys, together with the errors of structure and hardness and the more serious errors of imperfect homogeneity, make the extreme accuracy of the electrical datum illusory. The table furthermore contains λ_0, the electrical conductivity in microhms referred to the cubic centimeter. This reduction is made by means of mercury.‡ In the last two columns of table I, the value of α computed by the formula $\alpha+m=n\lambda_0$ and the corresponding errors are inserted. Of these results further mention will be made below, and I need here only state that the constants m and n given at the end of the table are those which I derived from all the relevant observations, by the method of least squares.

The compositions given are volume per cents, except in the cases of phosphides and arsenides of copper where mass per cents are meant.

In interpreting these results by graphic methods, it is necessary to proceed with caution, for inasmuch as specific resistance enters into them reciprocally, large values of resistance will only be inadequately represented. Neverthless, although the tables contain many such values, enough data remain to exhibit the striking linear character of the curves on which the gold, silver and copper points respectively lie. The initial tangent

* The metallic ingredient present in larger amount may be fitly used in designating the alloy.

† Matthiessen and v. Bose: Pogg. Ann., cxv, p. 353, 1862.

‡ Jenkin who made similar reductions in the case of pure metals by means of lead, arrives at somewhat different numbers. A perfectly satisfactory absolute table can not be deduced.

TABLE I.—*Showing Matthiessen and Vogt's results for the electrics of gold, silver, and copper alloys.*

	Alloy.	Composition.	λ'_0.	Observed $a \times 10^3$.	$\lambda_0 \times 10^3$ microhms.	Calculated $\delta a \times 10^3$.	$\delta a \times 10^5$.
Gold alloys.	Au	----	79	3·67	506	3·69	− 2
	AuCu	1·6 % Cu	56·1	2·65	359	2·63	+ 2
	AuCu	18·3 % Cu	16·1	0·75	103	0·79	− 4
	AuAg	20·1 % Ag	21·5	1·11	137	1·03	+ 8
	AuAg	47·9 % Ag	15·2	0·70	96	0·74	− 4
Silver alloys.	Ag	----	109	3·82	691	3·83	± 0
	*AgCu	1·5 % Cu	79·7	4·12 (?)	510	----	----
	AgCu	8·2 % Cu	80·3	2·75	514	2·88	−13
	AgCu	46·7 % Cu	74·9	2·80	480	2·69	+11
	AgPt	2·5 % Pt	31·6	1·24	202	1·20	+ 4
	AgPt	5·0 % Pt	18·0	0·77	115	0·73	+ 4
	AgPt	19·7 % Pt	6·7	0·33	43	0·34	− 1
	AgPd	23·3 % Pd	8·5	0·32	55	0·41	− 9
	AgAu	19·9 % Au	21·7	0·90	139	0·86	+ 4
Copper alloys.	Cu	----	102	3·87	653	3·98	−11
	CuAg	1·6 % Ag	89·5	3·45	573	3·54	− 9
	CuAg	4·8 % Ag	82·3	3·25	527	3·29	− 4
	CuAg	22·4 % Ag	69·8	3·03	447	2·85	+18
	CuAu	0·7 % Au	84·0	3·32	538	3·35	− 3
	CuAu	19·2 % Au	20·5	0·86	131	1·11	−25
	CuFe	0·5 % Fa	38·9	1·55	249	1·76	−21
	CuZn	5·0 % Fe	60·4	2·47	387	2·52	− 5
	CuZn	10·9 % Zn	46·9	2·05	300	2·04	+ 1
	CuZn	23·6 % Zn	21·3	1·88	136	1·14	+74
	CuZn	29·4 % Zn	21·7	1·27	139	1·15	+12
	CuZn	42·1 % Zn	21·8	1·37	140	1·16	+21
	CuSn	1·4 % Sn	62·5	2·68	400	2·59	+ 9
	CuSn	6·0 % Sn	19·7	1·00	126	1·08	− 8
	CuSn	11·6 % Sn	12·1	0·69	77	0·81	−12
	CuSn	12·3 % Sn	10·2	0·67	65	0·74	− 7
	CuSn	14·9 % Sn	8·8	0·55	56	0·69	−14
	CuP	1·0 % P	23·6	1·32	151	1·22	+10
	CuP	2·5 % P	7·3	0·48	47	0·64	−16
	CuAs	trace	61·1	2·64	391	2·54	+10
	CuAs	2·8 % As	12·9	0·74	82	0·84	−10
	CuAs	5·4 % As	6·3	0·52	40	0·61	− 9

* Rejected.

$$(\alpha + m = n\lambda_0)$$

Gold alloys	$m =$	$-0{\cdot}000045 \pm 0{\cdot}000030$
	$n =$	$+0{\cdot}00721 \pm 0{\cdot}00010$
Silver alloys	$m =$	$-0{\cdot}000112 \pm 0{\cdot}000031$
	$n =$	$0{\cdot}00538 \pm 0{\cdot}00085$
Copper alloys	$m =$	$-0{\cdot}000386 \pm 0{\cdot}000040$
	$n =$	$0{\cdot}000551 \pm 0{\cdot}00012$

concides with the initial curves throughout an enormous extent of their course. Matthiessen* who expressed a similar

* Matthiessen and Vogt: Phil. Mag. (IV), xxvii, p. 467, 1863; Pogg. Ann., cxxii, p. 19, 1864.

result under a somewhat involved form, was well justified in computing by means of it the conductivity of a pure metal from data found for metals slightly impure. This computation premises the truth of Matthiessen's other principle that with certain distinct exceptions, the electrical temperature coefficients of all pure metals are the same (cf. § 6).

4. After Matthiessen and Vogt the curious relation in question seems to have failed to enlist further attention, and I believe that the next systematic investigation is that made by Dr. V. Strouhal and myself in studying the electrics of the iron-carburets.* We did not, however, in the former paper reduce our results from the curvilinear form in which they appear when temperature coefficient is expressed in terms of resistance, to the curves of the present linear character; and hence I may expediently make this reduction here. If temperature coefficient (y) be expressed as a function of specific resistance (x), and if a curve be passed through all the points investigated for iron, steel, cast-iron, then the following principal coördinates obtain:

$x=$	15	45	70
$y=$	0·00420	0·00166	0·00130

Interpreted by an hyperbolic equation of the form $(x+l)(y+m)=n$, these data lead to constants

$$l=-3\cdot73, \qquad m=-0\cdot000706, \qquad n=0\cdot0394,$$

which do not reproduce the graphic curve satisfactorily. Neither is l by any means negligible, so that the reduction to linear forms is out of the question. At first sight this seems to prove that iron, steel and cast iron do not here form a unique series; that the resistance variation due to the change of carburation from iron to cast-iron is in its nature different from the resistance variation observed on passing from soft to hard steel. It appears below, however, that the favorable position of iron here unduly influences the result. I will temporarily withdraw both iron and cast-iron from the series. For steel alone we found (using the graphic method already referred to)

$x=$	15·9	28·9	45·7
$y=$	0·00423	0·00244	0·00161,

which data interpreted by the equation $(x+l)(y+m)=n$ now lead to the constants

$$l=0\cdot78, \qquad m=-0\cdot0001435, \qquad n=0\cdot0682.$$

Here the constant l is small, being only about five per cent of the smallest steel value of x admitted. Inasmuch as a result

* Cf. Wied. Ann., xx, p. 525, 1883; Bulletin U. S. G. S., No. 14, p. 15 to 25, 1885.

similarly favorable to the reduction to linear forms is obtained by adding cast-iron to the steel series, I have assumed the equation

$$x(y+m)=n.$$

Using this equation as a basis for the application of the method of least squares, the observations of Dr. Strouhal and myself lead to the results contained in the following table. These results are easily understood, and I need hardly add that according to § 1, the conductivity and temperature-coefficient of steel are respectively

$$\frac{1}{f(0)} \text{ and } \frac{f'(0)}{f(0)}.$$

TABLE II.—*Showing Strouhal and Barus' results for the electrics of iron-carburets,* $f(0)\,(f'(0)/f(0)+m)=n$.

Metal.	Temper.	$f(0)$.	$f'(0)/f(0)$.	$f'(0)/f(0)$.	Diff.
			Observed.	Computed.	
Steel	Soft	15·9	0·00423	0·00417	+ 6
"	Annealed light blue	18·4	360	366	− 6
"	" full blue	20·5	330	333	− 3
"	" yellow	26·3	280	269	+11
"	" light yellow	28·9	244	249	− 5
"	Glasshard	45·7	161	173	−12
Cast iron	--------	78·5	129	119	+10

$$m=-0{\cdot}000438\pm0{\cdot}000097$$
$$n=+0{\cdot}05930\ \pm0{\cdot}00151$$

Applied to steel alone, the constants computed by the method of least squares show even better agreement, viz:

$$m=-0{\cdot}000303\pm0{\cdot}000079$$
$$n=+0{\cdot}0620\ \ \pm0{\cdot}0017$$

I omit the details, with the mere remark that the difficulties of measurement with a molecularly unstable brittle body like hard steel are great.*

5. I desire now to add to these remarkable results the new data which I found for platinum alloys. I shall endeavor to make my series more nearly complete; to investigate points more nearly contiguous and nearer in position to the pure metal than was the case in the foregoing series, as well as to introduce a great variety of platinum alloys. For both in Matthiessen and Vogt's results, and in Dr. Strouhal's and my results, the position of the individual points is not always near

* Prof. J. H. Langley kindly called my attention to recent data for manganese steel. Looking up Fleming's work (Lum. electr., xxvii, p. 589, 1888), I found his results to be $s=68$ and $a=0{\cdot}0012$. In the above diagram $s=68$ corresponds to $a=0{\cdot}0013$, showing satisfactory accordance with experiment even in this region of abnormally high specific resistance.

enough together to fully exhibit the character of the locus between them. Unfortunately the body of platinum from which I made my alloys was not rigorously pure, an annoyance which in the course of other parts of my work I had occasion to regret. So far as the present investigation goes, however, the hurtful effect of the impure platinum body is *nil*. It will appear even more clearly below, that the law to be investigated is independent of the ingredients of the platinum alloy, except in so far as they modify its electrical conductivity. Alloying here is merely a means of modifying resistance, and the results are studied with regard to the resistance produced, not with regard to the way in which resistance is modified.

6. In making the alloys a weighed amount of platinum was fused down on a lime hearth before the oxyhydrogen flame. The foreign ingredient was then added, and the product after cooling rolled down and drawn to wire form. The initiated will know that accidents are not infrequent and that the tedious operations must often be repeated. The details of fusion and other manipulation are given in the Bulletin. To make the electrical measurement, selected parts (length 30^{cm}, diameter $0{\cdot}045^{cm}$) of the wires were annealed at a red heat and then wrapped in a single layer around a little cylinder of porcelain (length 2^{cm}, diameter $0{\cdot}45^{cm}$) in such a way that the spires of the helix did not touch. The ends were appropriately fused to copper terminals. The little helix was then introduced into the space of constant temperature of my *boiling tube*, and consecutively heated to 25°, 100° (steam), 357° (mercury vapor).

The results of the measurements are given in the following table. The series contains 57 alloys, of which Δ_0 denotes the density and s_0 the zero specific resistance. The table contains two values for the temperature coefficient α, the first of which, α_0^{100}, holds for the mean increase between 0° and 100°, the second between 0° and 357°, linear equations presupposed.

The wires A, B, C, are of the same platinum body (B), purified by long-continued intense fusions on lime, before the oxyhydrogen blow-pipe.

The relation of these data to each other may be exhibited graphically, and since α_0^{100} is very nearly $f'(o) : f(o)$, the following chart, figure 1, preferably represents α_0^{100} as a function of s_0. A few unmistakably exceptional values of α_0^{100} are either rejected or replaced by α_0^{357}, the justification of which is shown in the Bulletin.

The chart shows clearly, I think, that the alloys of platinum may be regarded as a class of materials possessing generic electrical properties: for the effect of alloying platinum with small amounts (< 10 per cent) of any other metal, is a variation of temperature-coefficient in a way which is independent of the

TABLE III.—*Showing the electrics of platinum alloys.*

No.	Metal alloyed to Platinum.	Δ_0	s_0	$10^3 \times a_0^{100}$	$10^3 \times a_0^{357}$
A	Platinum	----	12·0	2·90	2·65
C	Platinum	----	13·3	2·52	2·58
B	Platinum	21·31	14·9	2·30	2·22
1	Gold	21·29	18·5	1·78	1·62
2	Gold	21·22	22·1	1·45	1·33
3	Gold	21·17	24·7	1·27	1·09
4	Silver	21·16	19·1	1·80	1·61
5	Silver	20·99	22·3	1·46	1·02
6	Silver	19·40	34·0	1·02	0·71
7	Palladium	21·01	18·9	1·75	1·62
8	Palladium	20·54	20·9	1·53	1·48
9	Palladium	19·91	23·9	1·29	1·18
10	Iridium	21·27	19·4	1·72	1·61
11	Iridium	21·28	20·4	1·63	1·50
12	Iridium	21·32	23·6	1·28	1·21
13	Copper	20·68	31·8	0·89	0·83
14	Copper	20·60	33·6	0·80	0·72
15	Copper	18·80	63·6	0·20	0·20
48	Copper	20·92	25·3	1·27	1·14
49	Copper	19·56	53·6	0·29	0·15
16	Nickel	20·69	21·7	1·68	1·46
17	Nickel	19·89	26·8	1·34	1·19
18	Nickel	18·75	32·8	1·05	0·87
19	Cobalt	20·59	28·6	1·09	1·04
20	Cobalt	19·84	39·6	0·89	0·74
21	Cobalt	19·33	30·7	1·57	1·30
40	Cobalt	19·10	44·6	1·30	0·83
41	Cobalt	20·99	24·0	1·39	1·27
22	Iron	20·63	36·3	0·74	0·74
23	Iron	20·33	41·8	0·66	0·64
24	Iron	19·59	59·9	0·37	0·36
42	Iron	19·75	62·5	0·44	0·39
43	Iron	20·89	28·8	1·12	0·98
50	Steel	19·58	60·2	0·44	0·39
51	Steel	19·95	49·2	0·77	0·64
25	Chromium	20·91	27·4	1·14	1·06
26	Chromium	20·51	40·9	0·65	0·62
27	Chromium	20·16	52·4	0·56	0·49
44	Chromium	20·76	31·1	0·95	0·87
28	Tin	21·11	21·5	1·55	1·49
29	Tin	20·97	25·6	1·27	1·20
30	Tin	20·45	39·8	0·69	0·66
31	Aluminium	20·46	25·3	0·85	1·32
32	Aluminium	20·72	21·2	1·56	1·50
33	Manganese	20·81	25·6	1·28	1·14
34	Manganese	19·43	48·9	0·52	0·43
35	Molybdenum	21·26	16·0	2·13	1·94
36	Molybdenum	21·26	19·0	1·76	1·69
45	Molybdenum	21·30	16·4	2·06	1·88
37	Lead	21·18	14·6	2·28	2·23
46	Lead	21·24	17·0	2·02	1·82
38	Antimony	20·75	29·5	1·11	1·09
39	Bismuth	21·18	----	----	----
47	Bismuth	21·33	15 83	2·10	2·03
52	Zinc	20·10	44·2	0·51	0·32
54	Zinc	20·98	24·5	1·34	1·14
53	Cadmium	(21·3)	----	----	----

special ingredients of the alloy, and which depends only on the resistance-position of this alloy in the class. I venture to assert therefore that the arrangement of points is in accordance with a definite underlying law, with reference to which exceptional data are to be interpreted. The law in question appears to me particularly noteworthy as being among those which spe-

1.

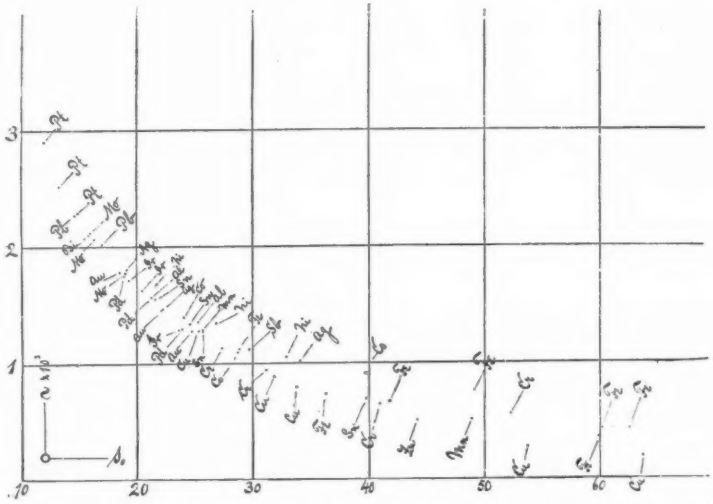


FIGURE 1.—Showing the relation between temperature-coefficient (α) and electrical resistance (s_0), in case of platinum alloys.

cially hold for the solid state. In his experiments on the conductivity of solid mercury, C. L. Weber* found its resistance to increase fourfold in virtue of fusion. Simultaneously with this variation, the temperature-coefficient of solid mercury (0·00455) falls to the relatively very low value (0·000927 between $-30°$ and $+45°$) which holds for the liquid metal. Weber points out the close approximation of the temperature coefficient of solid mercury to that of the other solid metals, and infers even closer agreement at temperatures sufficiently below the melting point of mercury. It is in a similar sense that in §1 I referred the properties to be investigated in this paper to a class of alloys characterized by high melting points.

* C. L. Weber, Wied. Ann., xxv. p. 245, 1885. The large variation of resistance at the melting point, observed in case of mercury and other metals and alloys (K, Na, etc.), suggests the striking adaptability of these substances for experiments on the relation between melting point and pressure; or in general on the continuity of solid and liquid state. Change of resistance is here the criterion of fusion.

7. Having thus obtained some general notions of the dependence of $f'(0)/f(0)$ on $f(0)$, it is in place to inquire more fully into the form of this dependence. I will proceed in a manner similar to that employed in §4, and postulate the hyperbolic equation $(x+l)(y+m)=n$. Availing myself of the chart, figure 1, selecting for preliminary computation a set of coördinates as carefully as possible from it,

$x=11{\cdot}7$	$y=0{\cdot}00300$
$20{\cdot}0$	164
$50{\cdot}0$	050

I find the constants l, m, n to be

$$l=-0{\cdot}1360, \quad m=0{\cdot}0002548, \quad n=0{\cdot}03764.$$

The values found for l, m, n are exceedingly significant. Since x varies between 10 and 70, l is in general much less than one per cent of x. This observation at once suggests the assumption of a simpler form of equation in which $l=0$. Again the positive character of m indicates that larger values of α_0^{100} would tend still further to simplify the equation $(x+l)(y+m)=n$. But $\alpha_0^{100} > \alpha_0^{357}$ follows from the experiments; hence also

$$f'(0)/f(0)=\alpha>\alpha_0^{100},$$

and therefore the postulation of $x(y+m)=n$ is altogether warranted.

To obviate the necessity of a complete recalculation of α, I used the following method of passing from α_0^{100} and α_0^{357} to α. If the values s, s', s'', correspond respectively to t, t', t'', and if

$$\frac{s}{1+\alpha t+\beta t^2} = \frac{s'}{1+\alpha t'+\beta t'^2} = \frac{s''}{1+\alpha t''+\beta t''^2},$$

it follows that

$$\alpha=\frac{(s'-s)(st''^2-s''t^2)-(s''-s)(st'^2-s't^2)}{(st'-s't)(st''^2-s''t^2)-(st''-s''t)(st'^2-s't^2)},$$

from which it is easy to deduce $\alpha-\alpha_0^{100}$ in terms of $\alpha_0^{100}-\alpha_0^{357}$. Now $st''-s''t=D''$ and $st'-s't=D'$ are already known from the earlier computations; and when a correction only is sought $s''t^2$ and $s't^2$ may here be neglected as compared with st''^2 and st'^2, respectively, t being small in comparison with t' and t''. Hence

$$\alpha-\alpha_0^{100}=\frac{\alpha_0^{100}-\alpha_0^{357}}{t''^2/t'^2\ D'/D''-1},$$

which equation, since the fraction $(t''/t')^2$ is constant, is a convenient form, and much of the correcting may be done mentally. I may add that the three quantities α_0^{100}, α_{100}^{357}, α_0^{357}

have similarly simple approximate relations to each other; for instance,

$$\alpha_0^{100}-\alpha_0^{357}=(t''-t'/t''-t)\ (\alpha_0^{100}-\alpha_{100}^{357}),$$

and since the fraction $(t''-t'/(t''-t)$ is constant, such reductions also are mental. I observe finally that the effect of these corrections is only a few units of the last figure. The methods are therefore sufficient.

8. Having made this preliminary survey, the data are available for the calculation of m and n by the method of least squares. It is expedient, however, before doing so, to put the postulated equation under the form

$$f'(0)/f(0)=n\,.\,1/f(0)-m,$$

where $1/f(0)$ is the zero value of the electrical conductivity of the alloy whose temperature-coefficient is α. This equation when operated on by the method of least squares does not give inordinate preference to high values of specific resistance; and since such high values can not be warranted with a greater degree of accuracy than the low values, the said equation may most expediently be made the basis of computation.

The following table contains the results and is intelligible without further explanation. The alloys 10, 11, 12 which I insert for completeness, were added subsequently to the calculation.

The probable errors of m and n indicate that the inaccuracy is largely incurred in the measurement of $f'(o)/f(o)$. The constant n is much more fully warranted.

9. Endeavoring to describe the platinum alloys as a class possessing generic electrical characteristics it is permissible to abstract from the minute and isolated behavior of the individual alloy. It appears that the electrical temperature-coefficient $(f'(o)/f(o))$, varies as a linear function of conductivity $(1:f(o))$, throughout the whole of the enormous variation of electrical resistance (10 to 65 microhms, c. c.), presented by platinum alloys not too highly alloyed (<10 per cent). In other words, if at $t°$, the specific resistance of a platinum alloy be denoted by $f(\chi,t)$, where t symbolizes temperature and χ is a variable parameter, then

$$f(\chi,0)\ (f'(\chi,0)/f(\chi,0)+0{\cdot}000194)=0{\cdot}0378.$$

It is perhaps not superfluous to remark in passing that if instead of the arbitrary temperature 0° C., some other value more in keeping with the qualities of platinum alloys had been selected, the constants m and n would present different values; and it is conceivable that correlated values of $f(t)$ and $f'(t)$ may exist for which the constant m is annulled, and for which the given equation takes the simple form $xy=n'$.

TABLE IV.—*Electrics of platinum alloys. Digest* $f(0)\,(f'(0)/f(0)+m)=n$.

No.	$f(0)$.	Observed $(f'(0)/f(0))\times 10^3$.	Calculated $(f'(0)/f(0))\times 10^3$.	Error $\times 10^3$.	Metal alloyed to platinum.
A	12·0	2·96	2·94	+ 2	Pt
C	13·3	2·50	2·66	−16	Pt
B	14·9	2·33	2·34	− 1	Pt
1	18·5	1·84	1·84	− 1	Au
2	22·1	1·49	1·51	− 2	Au
3	24·7	1·33	1·34	− 1	Au
4	19·1	1·87	1·79	+ 8	Ag
7	19·4	1·76	1·75	+ 1	Pd
8	20·4	1·67	1·66	+ 1	Pd
9	23.6	1·30	1·40	−10	Pd
10	19·4	1·76	1·75	+ 1	Ir
11	20·4	1·67	1·66	+ 1	Ir
12	23·6	1·30	1·40	−10	Ir
13	31·7	0·91	1·00	− 9	Cu
14	33·6	0·83	0·93	−10	Cu
15	63·6	0·21	0·40	−19	Cu
48	25·3	1·31	1·30	+ 1	Cu
49	53·6	0·34	0·51	−17	Cu
16	21·7	1·75	1·55	+20	Ni
17	26·8	1·39	1·21	+18	Ni
18	32·8	1·11	0·96	+15	Ni
19	28·6	1·11	1·13	− 2	Co
20	39·6	0 93	0·76	+17	Co
41	24·0	1·43	1·38	+ 5	Co
22	36·3	0·74	0·84	−10	Fe
23	41·8	0·67	0·71	− 4	Fe
24	59·9	0·37	0·44	− 7	Fe
42	62·5	0·46	0·41	+ 5	Fe
43	28·7	1·21	1·12	+ 9	Fe
50	60·2	0·46	0·43	+ 3	Steel
51	49·2	0·81	0·58	+23	Steel
25	27·4	1·17	1·19	− 2	Cr
26	40·9	0·66	0·73	− 7	Cr
27	52·3	0·58	0·52	+ 6	Cr
44	31·1	0·98	1·02	− 4	Cr
28	21·5	1·57	1·56	+ 1	Sn
29	25·6	1·29	1·28	+ 1	Sn
30	39·9	0·70	0·75	− 5	Sn
32	21·2	1·58	1·59	− 1	Al
33	25·6	1·33	1·28	+ 5	Mn
34	48·9	0·55	0·58	− 3	Mn
35	16·0	2·20	2·18	+ 2	Mo
36	18·9	1·78	1·80	− 2	Mo
45	16·4	2·12	2·11	+10	Mo
37	14·6	2·30	2·38	− 8	Pb
46	17·0	2·09	2·03	+ 6	Pb
38	29·5	1·12	1·09	+ 3	Sb
47	15·8	2·12	2·19	− 7	Bi
52	44·2	0·57	0·66	− 9	Zn
54	24·5	1·41	1·35	+ 6	Zn

$m = 0{\cdot}0001939 \pm 0{\cdot}0000233$

$n = 0{\cdot}03778 \quad \pm 0{\cdot}00054$

10. It is desirable finally to give as graphic an exhibit of the results taken collectively, as possible. Unfortunately any scale which clearly presents the results for gold, silver and copper, will crowd the results for platinum and the iron-carburets; and vice versa. Perhaps the following chart, fig. 2, will

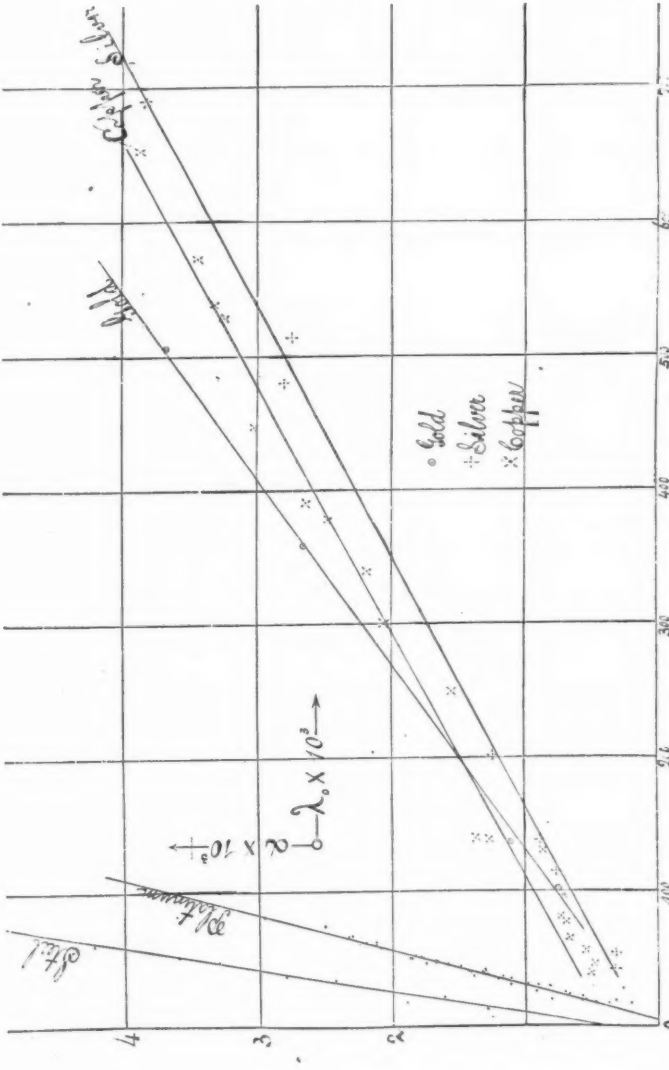


FIGURE 2.—Diagram of the relation between temperature coefficient (α) and conductivity (λ_0) for certain low percentage alloys.

represent the relation here involved. The constants of the lines drawn through the points are given at the end of the tables in §§ 3, 4 and 7. In the cases of silver, of gold, of platinum and of steel, the distribution of the points with reference to these lines is satisfactory, when the errors introduced by the mechanical treatment, by variations of hardness, and particularly by imperfect homogeneity are justly taken into account. In many cases, moreover, the percentage presence of foreign ingredient is greater than that specified in § 1. As all this is even more frequently the case with alloys of the oxydizable metal copper, the line computed by the method of least squares does not fairly represent these observations. The exceptional points here are the alloy of Cu with 22·4 per cent Ag, and the brasses with 23·6 per cent, 29·4 per cent and 42·1 per cent Zn. If these high per cents are rejected, the line for copper* will agree more nearly in character with the lines for gold and for silver, as it will tend more nearly to intersect the origin of coördinates (smaller numeric m). Applying the method of least squares for the case in which the inadmissible copper alloys are withdrawn, I find $m=-0{\cdot}278$ and $n=+0{\cdot}005655$, and of course a better agreement between observed and calculated α throughout. In figure 2, however, I have nevertheless inserted the line calculated for all the copper alloys in hand.

An interesting peculiarity of the steel line is that it leads to a larger value for the temperature-coefficient of iron† than that hitherto accepted. Comparisons of absolute values must however be made with caution, because of the great variety of electrical standards used by different observers. The high temperature-coefficient of iron is in conformity with relatively high values usually shown by alloys containing iron (cf. fig. 1.)

I desire finally to advert to the occurrence of the relatively *small* values of the constant, m, as computed for each of the series of silver, copper, gold, platinum and steel alloys. There is a marked tendency in all the cases stated to intersect the coördinate axes very near the origin. Inasmuch therefore as (§ 1) $\alpha=f'(\chi,0)/f(\chi,0)$ and $\lambda_0=1/f(\chi,0)$, the slopes of these lines are very nearly equal to $f'(\chi,0)$; or more rigorously to $f'(0,0)$, since their true nature is that of an initial tangent (cf. § 3.) In § 11 it appears that I am not asserting, however, that these lines do pass through the origin.

* Those who have worked with copper alloys, will know the extreme difficulty encountered in making the individual points conform to any uniform curve. The data usually make up a diagram of very broken lines, as in the above work of Matthiessen, and in results of Dr. Strouhal and myself. Further comment is made in the Bulletin.

† In his research on the conductivity of iron, Auerbach (Wied. Ann., viii, p. 479, 1879), discusses reasons for the exceptionally high value of the temperature-coefficient of iron.

11. Taking the results collectively, they point to a limit below which in the case of solid metals and at ordinary temperatures, neither electrical conductivity nor temperature-coefficient can be reduced; whence it appears that a lower limit of both conductivity and temperature-coefficient is among the conditions of metallic conduction, not to say of metallic state.* These considerations are suggestive and I shall therefore endeavor to make what I have in mind clearer. In the case of conduction in metals (solid or liquid) the effect of temperature is a decided decrease of conductivity, continuing apparently, as temperature increases, indefinitely.† In the case of conduction in non-metallic elements‡ or in electrolytes (solid or liquid) on the other hand, the effect of temperature is a decided increase of conductivity, which supposing the liquid state to be retained, continues as temperature increases. Hence conduction in metals is distinguished from conduction in electrolytes in this respect, that if the temperature coefficient in the one case (electrolytes) be regarded positive, its value in the other case (metals) must be negative. This leads me to inquire into the possible occurrence or the nature of a class of substances whose temperature-coefficient is zero; a class of substances in other words in which the metallic and the electrolytic modes of electric conduction may be supposed to converge.§

The point which I have in view, viz: the possibility of a continuous transition from metallic to electrolytic conductivity gains much in reasonableness by associating with good metallic conductivity the correlative property of optic opacity. Relations between electricity and light have been investigated and many experimental facts are known. Maxwell's electro-mag-

* Recent researches of v. Ettingshausen and Nernst and of C. L. Weber (Wied. Ann., xxxiv, p. 582, 1888), show that the resistance-temperature coefficient of bismuth is often negative between 0° and 100°. Edward Weston has made alloys of copper, ferro-manganese and nickel of which this temperature-coefficient is nearly zero or even negative (Science, xii, p. 56, 1888). These exceptions, the underlying cause of which is probably secondary and to be referred to structural or crystalline modification, emphasize the vast amount of evidence in favor of the normal behavior given in the text. I may add, for instance, that the temperature-coefficient of glasshard steel between 0° and 100°, would be nearly zero because of annealing.

† Following Benoit (C. R., lxxvi, p. 342, 1873) the electrical resistance of all metals increases with temperature at an accelerated rate, except in the case of platinum and palladium, where the rate of increase is retarded. Benoit observes at temperatures limited by the boiling point of zinc.

‡ Matthiessen (Pogg. Ann., ciii, p. 428, 1858), W. Siemens (Wied. Ann., x, p. 560, 1880) and others (Bergmann, Kemlein, Muraoka) find this to hold for modifications of carbon. Similar increases of conductivity are usually observed in the case of selenium and tellurium (Hittorf, W. Siemens, Mattheissen, and many others); but the relations here are complicated. Quite recently Duter (C. R., March 19th, 1888) has shown that sulphur conducts at its boiling point. It is this investigation which I have specially in mind in the text.

§ Something of the kind may perhaps occur in the case of some natural sulphides, but it is not open for systematic study and its nature is obscure.

netic theory of light furnishes a theoretical basis for the fact that true conductors are exceedingly opaque. The resistance of solid metals, however intensely they may be heated, is found to increase so long as temperature increases. Nevertheless the careful experiments which Govi* made to interpret an erroneous result of Secchi,† prove that solid metals even in extreme states of white heat remain opaque. In the case of liquid metals at extreme white heat the case is not so definitely established; and the question relative to the ultimate transparency of liquid metals at very high temperatures is an open one.‡ It is in the direction of ultimate transparency that the observed continuous increase of resistance with temperature seems definitely to point.

It is reasonable to infer that the transition from opaque to transparent§ will take place in the region of the critical temperature. At least such transition must ultimately occur; and I am led to conjecture that the said transition from opaque to transparent will be accompanied by a change of the values of the electrical temperature coefficient, passing from the negative value which holds for the liquid metal, to the positive value which will probably hold for the gaseous metal, continuously through zero. The fact that conduction in gases is of an electrolytic nature was proved by Varley,‖ who showed that after the polarization of the electrodes is overcome, gases obey Ohm's law. The electric *strength* of air is known to diminish rapidly as temperature is increased. Working with hot gases carefully insulated and protected from flames, Maxwell¶ was unable to obtain conduction either in hot gases like air or in hot metallic vapor like Hg or Na. At higher temperatures (red heat) the researches of Blondlot,** confirming the observations of E. Becquerel,†† prove that hot gases are conductors, and that at temperatures sufficiently high $\frac{1}{1000}$ volt is enough to set up a current. Hence in their thermal relations also, gases ultimately partake of the nature of an electrolyte, and the occurrence zero value of the temperature coefficient may be reasonably associated with the critical temperature of the metallic liquid, passing continuously from the liquid into the gaseous state.

* Govi, Comptes Rendus, lxxxv, p. 699, 1877.

† Secchi, Comptes Rendus, lxiv, p. 778, 1867.

‡ W. Ramsay, Chem. News, lv, pp. 104 and 175, 1887; Turner, ibid., p. 163, 1887; Professor T. Sterry Hunt has given the question some attention. Kundt's recent experiments (Wied. Ann., xxxiv, p. 469, 1888), on the refractive index of metals will doubtless lead to more definite results than the data now in hand.

§ The jet of liquid hydrogen escaping from Pictet's apparatus appeared steel-blue, and was opaque for a distance of about 12^{cm}.

‖ Varley, Proc. Roy. Soc., xix, p. 236, 1871.

¶ Maxwell, Elementary Treatise on Electricity, ed. by Garnett, 1881, §§138, 139.

** Blondlot, Comptes Rendus, xcii, p. 870, 1881; ibid., civ, p. 283, 1887.

†† E. Becquerel, Comptes Rendus, lv, p. 1097, 1867.

Art. XLIV.—*On the Puget Group of Washington Territory;* by Charles A. White.

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About two years ago, Prof. J. S. Newberry placed in my hands for study a small collection of fossil mollusca which he had obtained from the coal-bearing formation in Puget Sound basin in Washington Territory. This collection represents a hitherto unpublished brackish-water fauna, which characterizes a formation that possesses unusual interest. All the discovered species of this fauna will be described and illustrated in Bulletin 50 of the U. S. Geological Survey, where also the formation will be discussed. Twelve species have been recognized, of which the following is a list: *Cardium* (*Adacna?*)——*?*, *Cyrena brevidens*, n. s., *Corbicula Willisi*, n. s., *C. Pugetensis*, n. s., *Batissa Newberryi*, n. s., *B. dubia*, n. s., *Psammobia obscura*, n. s, *Sanguinolaria? caudata*, n. s., *Teredo Pugetensis*, n. s., *Neritina* ——*?*, *Cerithium* ——*?* and an undetermined gasteropod.

The formation from which these fossils were obtained is known to occupy a large part of Puget Sound basin, and to extend upon the western flank of the Cascade range, which forms the eastern side of the basin; but all the boundaries of the area which it occupies are not at present known. Besides these strata which lie to the west of the Cascade range, other similar deposits are found upon its eastern flank, as well as at certain localities among its higher mountains. All these deposits are believed to belong to one and the same formation, although those within, and east of, the Cascade range have not yet furnished any molluscan fossils similar to those found upon the western side of the range. Certain unique features of the fauna referred to show that the strata in which the remains were found were deposited in a body of water which was quite separate from that in which was deposited any one of the coal-bearing formations in the Pacific Coast region or elsewhere. Its zoological character indicates that the body of water in question was an estuary; and the extent of the district within which the deposits have been found shows that that estuary was a very large one.

The most complete information that has yet been published concerning this formation appeared in volume xv of the reports of the Tenth U. S. Census, pp. 759–771, plates lxxxii–cii. That publication, which is entitled "A Report on the Coal Fields of Washington Territory," is by Mr. Bailey Willis, who accomplished the work upon which his report is based under

the auspices of the Northern Transcontinental Survey. The special object of his report having been the presentation of the coal resources of that region, the discussions are confined mainly to its coal-bearing formations; and the report therefore does not embrace a full account of the geology of the whole region. Still, Mr. Willis has given some comprehensive facts as well as many elaborate details concerning this formation in the report referred to; and as my own field labors upon the Pacific coast have not extended to the northward of the Columbia river, my knowledge of many of the facts which are stated in the following remarks has been derived from him, and from Professor Newberry.

The orogenic elevations of the Pacific Coast region extend in two lines which are approximately parallel with each other and with the coast. The eastern line consists of the Sierra Nevada in California and of the Cascade range in Oregon and Washington Territory. The western line, known as the Coast range in California, is more or less distinctly recognizable through western Oregon, and extends northward of the Columbia river into Washington Territory; but it there sinks to low hills before reaching the Olympic cluster of mountains, which forms the northern end of the line. This cluster is a prominent feature of that district, its higher peaks rising to more than 8000 feet above the sea level.

The relief of this great strong-featured Pacific Coast region is the product of several uplifts, differing in time, extent and locality, the whole history of which is not yet clearly understood but the facts of interest in this connection may be provisionally stated as follows. The Cascade range, which has been recognized as distinct in structure and origin from the Sierra Nevada range, although in a general line continuous with it, has been considered to be itself simple; but it is in reality quite complex. In Oregon it is composed of erupted material, often of great thickness, which has been observed to rest upon nearly horizontal sedimentary strata of Cretaceous age; and in southern Washington Territory it consists of enormous masses of erupted rocks overlying highly flexed sedimentary strata of late Mesozoic or early Tertiary age. In the northern half of the same Territory the range is made up entirely of granite, crystalline schists and volcanic rocks. As bearing upon the subject in hand, it may be stated here that the Tertiary rocks, which prevail in the Coast range generally seem to be wanting in the Olympics which, in this respect and in their composition, resemble the northern portion of the Cascade range.

Between the two long lines of orogenic elevation before referred to, lie the great valleys of the Sacramento and San Joa-

quin rivers in California, of the Willamette in Oregon, and of Puget Sound (known as Puget Sound basin) in Washington Territory. The latter valley was the scene of deposition of the coal-bearing series of strata which is characterized by the molluscan fauna already mentioned.

Mr. Willis describes this formation as consisting of "alternating beds of yellow and fine grained sandstones and very fine arenaceous shales interstratified with many beds of carbonaceous shale and coal; the individual strata of sandstone and shale, from 20 to 200 feet thick, maintain the same general character wherever observed." He further says that a section measured near the town of Wilkeson in Puget Sound basin "gives a minimum thickness of 13,200 feet, with a probable maximum of 14,500 feet." The surprise that one feels upon learning of the extraordinary thickness of this estuary deposit is increased by Mr. Willis's statement that, so far as he could observe, the contained molluscan fauna ranges vertically through the whole formation.

This is surely a remarkable deposit for one of estuary origin, but it is so regarded in consideration of the following facts: No trace of an open sea fauna has been found in it, while all the molluscan remains that have been found in it are related to estuary forms. These remains embrace species of the Corbiculidæ, the members of which family are known to range from brackish to fresh waters. These forms are associated with certain others whose living congeners are known to range from marine to brackish waters but not into fresh waters; and the strata of this deposit contain an abundance of vegetable remains, which doubtless came from local swamps and adjacent shores.

No specimens of this fauna have yet been discovered beyond the present limits of Puget Sound basin, nor in any other formation than those from which Professor Newberry's collection was made. But if, as is inferred from a general similarity of lithological characters, the absence of marine fossils, the presence of coal beds and of identical species of plant remains, and from similarity of position with relation to older and later formations, the deposits which are found upon the eastern side, as well as within the body, of the Cascade range in southern Washington Territory, constitute parts of the same formation which is found upon the western side, the scene of its deposition extended much beyond the limits of Puget Sound basin.

This conclusion of course implies that the portion of the Cascade range upon which those strata are found was not then elevated, as was the northern portion, and that the outline of the area within which this deposit was made was very different from

what would be suggested by any of the present topographical features of the region. That the present topographical features of that region differ greatly from those which prevailed during the Puget epoch is indicated by other observations of Mr. Willis. For example, he noted the absence of the Puget Group high up in both the Olympic, and the northern Cascade mountains, which leads him to believe that while that formation was being deposited, the former mountains constituted an island, and the latter, a peninsula. It is hardly to be supposed, however, that the topographical features of that region were permanent throughout the whole of the Puget epoch, because the range of the molluscan fauna through the whole thickness of the formation, as already mentioned, indicates that there was a constant subsidence over the whole area within which the deposit took place, during the whole time of its accumulation. Certain topographical changes in that neighborhood at least, must have accompanied such a subsidence.

In the report of Mr. Willis, already referred to, he not only regards this formation as equivalent with the Laramie Group, but he provisionally applies the same name to it. His reasons for doing so, in addition to the fact that, like the Laramie, this group apparently rests directly upon upper Cretaceous marine strata, appears in the following paragraph which he has kindly furnished me from an unpublished report of his upon a district which lies to the eastward of Puget Sound basin.

"The Laramie? of the Wenatchie Valley."

"The Wenatchie river cuts a section across unmetamorphosed conglomerates and sandstones bent in broad folds over axes having a general north and south trend. This formation flanks the Peshastan range on both sides, occurring on the south on Schwak creek, and in the Klealim valley, and forms some of high crests of the Cascade range north of Natchez. It is the last formation deposited before the elevation of the Cascade range and its spur, the Peshastan, and is thus identified, as well as lithologically and in its stratigraphic relations, with the Puget Sound Coal measures, the latter having been assigned to the Laramie by Prof. J. S. Newberry on the evidence of the leaf impressions."

I think that all the known evidence is strongly in favor of the view taken by Professor Newberry and Mr. Willis as to the equivalency and probable contemporaneity of the Puget Group with the Laramie; but it may be regarded as certain that these two formations were deposited in separate bodies of water and under materially different conditions; and that they were separated by a land area of considerable breadth. The area, however, was not so broad as to make it unreasonable to suppose

that an arboreal flora extended entirely across it, and scattered its autumnal leaves into the Laramie sea upon the one hand and into the Puget estuary on the other. Possibly it may yet appear that terrestrial vertebrate, and molluscan faunas also extended across the same area by the discovery of their remains in both the Laramie and Puget groups.

Besides the evidence which is furnished by the character of the gill-bearing fossil mollusca of the Laramie and Puget groups respectively that they were deposited in separate bodies of water, satisfactory evidence exists that the Laramie outlet was upon the Atlantic side of the continent, and that the Puget outlet was upon the Pacific side. Admitting that these conditions existed there seems to be little probability that the two faunas had a common origin. Under such circumstances I think it better to use separate names for the two formations; and I have accordingly proposed the name of Puget Group for the formation which forms the subject of this article.

As to what were the original boundaries of the Puget estuary deposit comparatively little is definitely known, as already intimated. It is probable also that much will always remain unknown upon this point owing to the great erosion which the strata have suffered, and to the presence of large portions of the volcanic outflows which have so largely covered them. Taking into consideration the extreme points at which strata of this group have been found, including those which lie to the east of, and among the Cascade mountains, the present indications are that the Puget Group originally occupied an area of several thousand square miles.

That the body of water in which the Puget Group was deposited was an estuary, and not a land-locked sea, as was the Laramie, is indicated, as already shown, by its molluscan fauna.* But in what manner the Puget estuary was separated from the open ocean we have as yet little information. A natural inference would be that the Olympic island formed part of such a barrier, but the discovery of marine fossils in the valley of Dwamish river, the strata inclosing which were presumably formed contemporaneously with at least a portion of the Puget Group, would seem to show that the estuary barrier was, a part of the time, at least, to the eastward of Olympic island.

Although the contemporaneity of the Puget and Laramie groups apparently need not be questioned, the stratigraphical relation of the former to the Téjon Group, which is presumably of approximately the same age, has not been satisfactorily determined. Vertebrate and vegetable paleontology have fur-

* The apparent absence of this peculiar fauna from the more eastern strata suggests that they were deposited nearer to the influx of fluviatile waters, which being therefore entirely fresh did not afford a congenial habitat for the species which prevailed in the western and brackish part of the estuary

nished no evidence upon this point. The invertebrate remains which each formation has furnished afford no means of comparison because those of the Puget Group are estuarine and those of the Téjon Group marine: and because the estuarine types of molluscan life are always of little if any value as indicating geological age. Therefore we are reduced to stratigraphic evidence alone in attempting to correlate the Puget, with the Téjon Group.

Mention has just been made of the discovery of strata containing marine fossils at a locality on Dwamish river in Puget Sound basin, and not far from typical exposures of the Puget Group. A considerable proportion of the fossils found there have been identified with Téjon species, and those Dwamish valley strata doubtless represent a part of the Téjon Group.

Mr. Willis, who has studied the stratigraphy there in connection with his work before referred to, regards the position of these marine strata with reference to those of the Puget Group as having been deposited not earlier than those of the upper portion of that group. This view of the stratigraphical relations of the Dwamish river strata with those of the Puget Group, together with the fact that the fossils of the former are of marine origin, suggests that they were deposited in marine waters towards the close of the great subsidence that accompanied the deposition of the Puget Group, and indicates that the latter group is a local, although a large, chronological representative of a part, or the whole, of the Chico-Téjon series.*

Now if the strata of the Puget Group were deposited, even in part, contemporaneously with the Chico-Téjon series, it is probable that some of the species of that series which were capable of entering brackish waters may yet be found in the Puget strata, and that some of the Puget fauna which were capable of entering marine waters may yet be found associated with Chico-Téjon species. As a matter of fact, however, no evidence of such a commingling of the species of the two faunas has yet been discovered. So far, therefore, we have no paleontological evidence of the contemporaneity of the Puget Group with the Chico-Téjon series.

Although no serious doubt is entertained that the Puget Group was deposited in estuarine waters there are certain facts which are somewhat perplexing when considered in connection with an acceptance of that view. The known area within which strata of that group occur shows that the Puget estuary was of such great extent that it is difficult to understand how so large a body of water could have been uniformly kept so

* It also seems to indicate that the western barrier of the Puget estuary was at that time and place, not far from the middle of the present Puget Sound basin, but it is probable that the position of the barrier was shifted from time to time, during the existence of the estuary.

nearly fresh as to afford a congenial habitat for such a molluscan fauna as it is known to have possessed, and as was necessary for the accumulation of the great thickness of strata in which the remains of that fauna are found, during so long a period of time.

That is, it is difficult to understand how that comparatively narrow portion of the continent between the then existing Laramie hydrographic basin on the east, and the Puget estuary on the west could have furnished a sufficient flow of fluviatile water to keep nearly fresh so large an estuary, and keep off the encroachment of adjacent marine waters. Even so large a flow as is now discharged by the Columbia would seem to have been insufficient unless the outlet of the great estuary was greatly narrowed by land barriers.

Again, the evidence presented by Mr. Willis, and also that afforded by the fossils, which range without material change through a large part of the vertical series, seems to be conclusive that essentially uniform estuarine conditions were preserved over the whole area now occupied by the Puget Group from the time of the deposition of its earliest, to that of its latest strata. This evidence also discloses the remarkable fact that during that time there was a constant subsidence over the whole area, until it had reached a maximum of not less than twelve thousand feet.

It is certainly difficult to understand how so great a subsidence could have taken place without such a simultaneous elevation of the adjacent land area as would have materially changed the character and uniformity of the supply of fluviatile waters to the estuary, or have added a land area to the westward of it. Indeed, it is difficult to understand how even a less subsidence could have taken place without materially modifying the character of the great estuary itself, or even submerging its whole area beneath marine waters.

The biological relations of this Puget fauna to other faunas possess peculiar interest. For purposes of comparison one instinctively turns to the molluscan fauna of the Laramie Group; but in doing so important differences appear. It is true there are two species of Corbicula in the Puget fauna that are so closely like Laramie forms as to suggest specific identity upon casual examination; but the differences between the two faunas are strikingly shown by the family and generic characters of the other members of the Puget fauna as compared with the Laramie fauna.

For example, a species of Teredo has been found in the Puget Group, but no member of the Teredinidæ has yet been found in the Laramie. Two species of the Puget fauna are referred to the Tellinidæ, but no member of that family has

yet been found in the Laramie. But the generic form which gives an especially unique character to the Puget fauna is that of Batissa. This genus has not hitherto been known to occur in North America, in either a fossil or living condition; nor has it been found nearer to this continent than certain of the Pacific islands. Still the hinge characters observable in these Puget estuary specimens leave no room for reasonable doubt that they are strictly congeneric with Batissa. Indeed a species of that genus which is now living upon the Fiji Islands is closely related to this fossil form.

Certain interesting relationships between Asiatic and North American faunas have been noticed by naturalists, which are recalled by this occurrence of Batissa in the Puget fauna. Assuming that these relationships are those of genetic succession, we naturally desire to know the direction of the lines along which their geographical dispersion took place. For example, was it toward, or from the present North American continent that the dispersion of Batissa has occurred? If it was from this continent, it is remarkable that none of its progeny have survived in any of the present continental waters; and it is equally remarkable that no evidence of its former existence in North America has been discovered except that which the Puget fauna has furnished. If the dispersion of Batissa was toward this continent, it seems to have only reached the present Pacific coast region about the close of the Cretaceous period, and to have there and then become extinct; while it has continued its existence on certain islands of the Pacific to the present time. But all the known facts concerning the genus Batissa are insufficient to throw much light upon its geological history or geographical dispersion. Even the Corbiculidæ, the family to which Batissa belongs has a less completely known geological history in North America than has the Unionidæ.

ART. XLV.—*Two Sulphantimonites from Colorado;* by L. G. EAKINS.*

THE mineral first to be described was sent to the Denver laboratory of the U. S. Geological Survey in the latter part of 1885, by Mr. E. R. Warren, of Crested Butte, Colorado.

At that time a hasty qualitative examination was made, establishing the fact that it was a sulphantimonite of lead, and since then nothing more has been done with it until the present analysis was made.

*Read before the Colorado Scientific Society, Meeting of June, 1888.

This mineral comes from the "Domingo" Mine, on the ridge between Dark Cañon and Baxter Basin, Gunnison Co., Col.; in which locality it is known as "mineral wool." It consists of aggregates of small acicular crystals, forming matted, wool-like masses in the cavities of a highly decomposed gangue rock of siliceous material mixed with some calcite. It is dull, grayish black in color, with occasional spots of iridescence, due undoubtedly to a slight superficial oxidation.

In procuring material for analysis, a lot of loose material sent by Mr. Warren was slightly crushed and rubbed with water in a mortar and poured off, the fine needle like crystals floating off readily; this was afterward purified by a re-treatment in the same manner, and then subjected for a short time to the action of dilute hydrochloric acid to remove the slight amount of attached calcite. The material obtained in this manner appeared under the microscope to be perfectly pure and homogeneous with the exception of a slight amount of gangue still remaining.

No crystalline form could be made out, and on account of its peculiar nature no attempt has been made to determine either specific gravity or hardness. Heated before the blowpipe it fuses readily without decrepitation; in the closed tube it gives a slight sublimate of sulphur only; in the open tube it gives off sulphurous acid and dense white fumes of oxide of antimony; heated strongly the antimony all volatilizes, leaving a fused residue of sulphate of lead, slightly colored by the iron present; on charcoal it gives the lead and antimony coatings, and in the reducing flame with soda, a lead button. It is soluble in hot, strong hydrochloric acid with evolution of hydrogen sulphide.

The analysis is as follows:

		Atomic ratios.	
Ag	trace		
Cu	trace		
Pb	39·33	÷207=·190	·222
Fe	1·77	÷ 56=·032	
Mn	trace		
Sb	36·34	÷120=	·303
S	21·19	÷321=	·662
Insoluble gangue,	·52		
	99·15		

Dividing these atomic ratios by ·222, we get:—

Pb, Fe,	= 1	= 3
Sb,	1·36	4·08
S,	2·98	8·94

Giving the formula:—$(Pb, Fe)_3Sb_4S_9$, or $3(Pb, Fe)S, 2Sb_2S_3$.

. This mineral, it is seen, fills a place in the group—3RS, $2(As, Bi, Sb)_2S_3$, of which there are but few good examples, and which until now has not had an antimony representative.

The somewhat low summation of the analysis is probably due to two causes; first, a small amount of soluble gangue which was present and undetermined; second, the sulphur is about four-tenths of one per cent less than required, due to the slight natural oxidation of the mineral together with an additional amount induced by treatment with dilute hydrochloric acid for the removal of calcite. In addition to the complete analysis given, there were additional determinations made of lead, antimony and sulphur, the results obtained being in strict agreement with those given above.

The second of these sulphantimonites was collected in the summer of 1887, by Mr. Whitman Cross; it comes from a mine on Augusta Mountain, Gunnison Co., Col., this locality being about one mile east of the "Domingo" mine.

Locally this mineral is also known as "mineral wool," and although differing considerably in appearance from the one just described, they were, on account of the similarity of occurrence, considered as probably identical.

It occurs in a siliceous gangue together with pyrite and sphalerite, and forms groups of acicular crystals which are elongated prisms, deeply striated; but whose form could not be determined.

The individual crystals of this mineral are considerably larger than those of the one previously described, and in consequence they do not tend so much to form matted aggregates. Its color is a bright, steely, gravish black, with no tendency toward tarnish or iridescence. The separation of this mineral from the accompanying ones and the gangue, was a matter of considerable difficulty; on account of their size the crystals could not be successfully washed out from the other material, but by the use of a rapid current of water, and the Thoulet method, a small quantity was finally procured perfectly free from everything except some pyrite, and that had no effect upon the analysis, as the mineral was dissolved in a mixture of hydrochloric and tartaric acids, leaving the pyrite unattacked; it was then filtered through a Gooch crucible, and the amount of pyrite determined and deducted from the material taken. The fact that but a trace of iron was found in the analysis is conclusive proof that the pyrite was practically unattacked.

Blowpipe characteristics are the same as in the one before described.

The analysis is as follows:

		Atomic ratios.
Ag	trace	
Pb	55·52	÷207=·268
Fe	trace	
Sb	25·99	÷120=·217
(calculated) S,	18·98	÷ 32=·593
	100·49	

Dividing these atomic ratios by ·217 we get:

Pb,	= 1·24	= 4·96
Sb,	1	4
S,	2·74	10·96

Giving the formula:—$Pb_5Sb_4S_{11}$ or $5PbS, 2Sb_2S_3$.

We have here, in formula, a freieslebenite in which instead of lead and silver, the silver has been completely replaced by lead, and although the crystallographic agreement of this mineral with freieslebenite has not been established, there seems to be no good reason for not referring it to that species.

Laboratory, U. S. Geological Survey, Washington, D. C.

ART. XLVI.—*On the Voltametric Measurement of Alternating Currents;* by A. E. KENNELLY.

IT has until quite recently been generally supposed that an electric current reversing its direction with the frequency that characterizes what is commonly called an alternating current, would not decompose water visibly, or in fact that if any decomposition did take place at the electrodes, the recombination at the reversal was so speedy and complete that no free gas was developed. It has been shown, however, lately, in a paper by MM. Maneuvrier and Chappuis, read before the Académie des Sciences, that when the electrodes are small, free decomposition does take place, mixed gas being liberated at each. Since that time Professors Ayrton and Perry have contributed to the data on the subject in an article appearing in "The Electrician" of London, July 13, 1888, and in which some very interesting phenomena observed with polarized electrodes are described, while it is mentioned that the quantity of gas liberated under given conditions is a function not only of the current density per unit surface of electrode but also of the rate of alternation.

No statement of the connection that exists between these variables seems to have yet been published. The following experiments made recently at Mr. T. A. Edison's laboratory

for the purpose of investigating this matter show that under certain conditions the quantity of gas liberated is in very close accordance with that which a continuous current of equal strength would supply, and hence afford ground for the hope that it will shortly be possible to measure the strengths of alternating currents by the voltameter as closely and as conveniently as in the case of continuous currents.

Two methods have been tried. (1) The condenser method or incomplete metallic circuit. (2) The ordinary method with complete metallic-and-liquid circuit.

Several series of measurements have been made, all agreeing very fairly. The following series taken at one time will suffice for all.

The source of the alternating current was a Siemen's alternating dynamo machine designed for 100 volts, the electromotive force being readily under control through the current in its field magnets; the speed of revolution on the occasion of this experiment was steady at 1470 per minute. At this speed its alternations, being 8 to the revolution, are 196 per second.

The voltameter was of special construction. An ordinary glass evaporating dish $11{\cdot}5^{cms}$ in diameter and 6·3 high was filled about two-thirds with a 10 per cent (by weight) solution of pure sulphuric acid in distilled water, the density of this solution being 1·065 at 19° C. At the bottom of the dish was immersed a disk of resinous material 5^{cms} in diameter and $1{\cdot}2^{cms}$ high. Twelve platinum wires of different lengths but equal

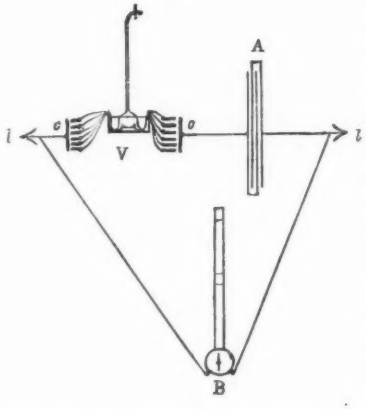
Nos. of couple.	Diameter, cms.	Circumference, cms.	Length of each wire, cms.	Cylinder surface, sq. cms.	Section surface, sq. cms.	Total surface of each plate, sq. cms.	Sum of surfaces in multiple.	Great'st h'rizont'l distance betw'n wires forming couple.	Least horizontal distance.
1	0·0178	0·0559	1·5	$8{\cdot}39\times10^{-2}$	$0{\cdot}025\times10^{-2}$	$8{\cdot}415\times10^{-2}$	$21{\cdot}555\times10^{-2}$		
2	"	"	1·0	$5{\cdot}59\times10^{-2}$	"	$5{\cdot}62\times10^{-2}$	$13{\cdot}140\times10^{-2}$	$3{\cdot}7^{cms}$	1^{cm}
3	"	"	0·8	$4{\cdot}47\times10^{-2}$	"	$4{\cdot}50\times10^{-2}$	$7{\cdot}520\times10^{-2}$		
4	"	"	0·4	$2{\cdot}24\times10^{-2}$	"	$2{\cdot}27\times10^{-2}$	$3{\cdot}020\times10^{-2}$		
5	"	"	0·1	$0{\cdot}56\times10^{-2}$	"	$0{\cdot}585\times10^{-2}$	$0{\cdot}750\times10^{-2}$		
6	"	"	0·025	$0{\cdot}14\times10^{-2}$	"	$0{\cdot}165\times10^{-2}$	$0{\cdot}165\times10^{-2}$		

diameter ($0{\cdot}0178^{cms}$) projected vertically from the upper surface of the disk, so as to stand in a ring of 4^{cms} diameter and equidistant from each other. These wires were ranged from $1{\cdot}5^{cms}$ down to $0{\cdot}025^{cms}$ in length, the corresponding wires across one diameter having as closely as possible equal lengths. Connections with rubber-covered wires sealed in the material of the

disk made six little separate voltameters each with its own pair of insulated leads. By uniting more or less of these leads outside the dish, the voltameter might be made to comprise any or all of the couples of electrodes, thus enabling a considerable range of electrode area to be at command as shown by the preceding table.

Over this sextuple voltameter there rested a glass bell 7^{cms} in diameter, terminating after 10^{cms} of elevation in a vertical glass tube of uniform bore $37{\cdot}5^{cms}$ long and about $0{\cdot}6^{cms}$ internal diameter, closed at the top by a rubber tube and clamp. This tube was graduated for volume by comparison with a burette and found to have a capacity per linear centimeter from several measurements of $0{\cdot}2684 \pm 0{\cdot}002$ c. c. In using the instrument, the tube and bell were filled with solution and gas electrolytically generated until the latter stood at a certain mark near the top. All being ready, the measured current was then passed through the apparatus for a noted interval, at the end of which the length of tube occupied by gas was measured downward from the fiducial mark.

1.



In the condenser method the connections were as shown in the diagram: where A is the adjustable condenser, V the voltameter with commutators *c c* for connecting the separate couples of plates in multiple, B a Cardew voltmeter, and *l l* the leads to the dynamo.

Under these conditions we know that the absolute quantity of current passing through the voltameter assuming that the periodic variation of electromotive force follows the sine law:

$$Q = n \pi e k t \times 10^{-7} \qquad (1)$$

where Q is the absolute quantity of electricity that traverses the voltameter in time *t*; *e* is the mean alternating potential difference as indicated by the Cardew voltmeter B; *k* is the capacity of the condenser A in microfarads; and *n* is the number of alternations per second. This formula is thus independent of the resistance of the voltameter, which is quite negligible under these conditions. If V_0 be the volume of gas at zero Centigrade theoretically decomposed by a continuous cur-

No. of trial.	Sept. 15. Time of passage of current.	Seconds elapsi'g. t.	Voltameter couples in circuit.	Area of each compound electrode. sq. c.	Capacity K inserted in A.	Cardew reading.	Corresponding mean altg. voltage. volts.	Length of tube filled by gas. cms.	Corresponding volume. c. c.	Equivalent current c. abs. units.	Calculated volume V_0. c. c.	Volume corrected to temp. 19° C. c. c.	Ratio of observed vol. / Calculated vol.	Density of current per cm. of electrode. abs. units.
1	$17\frac{13{\cdot}00}{21{\cdot}20}$	500	1, 2, 3, 4, 5, 6	$21{\cdot}56\times10^{-2}$	4ϕ	87° 45′	97·3	5·15	1·383	$2{\cdot}4\times10^{-2}$	20·87	22·32	0·062	0·112
2	$17\frac{31{\cdot}00}{36{\cdot}00}$	300	4, 5, 6	$3{\cdot}02\times10^{-2}$	4	87°	96·8	18·7	5·02	$2{\cdot}39\times10^{-2}$	12·37	13·23	0·380	0.79
3	$17\frac{40{\cdot}00}{44{\cdot}00}$	240	5 and 6	$0{\cdot}75\times10^{-2}$	4	85° 30′	95·7	30·55	8·20	$2{\cdot}36\times10^{-2}$	9·78	10·46	0·784	3·15
4	$17\frac{53{\cdot}00}{55{\cdot}00}$	120	6	$0{\cdot}165\times10^{-2}$	2	82°	93·1	9·3	2·50	$1{\cdot}15\times10^{-2}$	2·38	2·55	0·980	6·97
5	$17{\cdot}\frac{57{\cdot}00}{18{\cdot}00{\cdot}00}$	180	6	$0{\cdot}165\times10^{-2}$	4	84° 20′	94·8	27·7	7 44	$2{\cdot}34\times10^{-2}$	7·27	7·78	0·956	14·18
6	$21{\cdot}^{20{\cdot}06}$		6	$0{\cdot}165\times10^{-2}$	4	83°	93·9	On making contact one of the electrodes of couple							No.6 burned.
7	$21{\cdot}\frac{32{\cdot}00}{35{\cdot}00}$	180	one of 5 and opposite of 6.	$0{\cdot}585\times10^{-2}$ / $0{\cdot}165\times10^{-2}$	4	85° 15′	95·4	27·75	7·45	$2{\cdot}35\times10^{-2}$	7·31	7·82	0·953	Av'ge=6·26
8	$21{\cdot}\frac{39{\cdot}00}{42{\cdot}00}$	180	do.	do.	2	81°	92·4	11·65	3·13	$1{\cdot}14\times10^{-2}$	3·54	3·78	0·826	Av'ge=3·04
9	$21{\cdot}\frac{46{\cdot}00}{49{\cdot}00}$	180	do.	do.	3	82°	93·1	19·05	5·11	$1{\cdot}73\times10^{-2}$	5·35	5·72	0·893	Av'ge=4·61
10	$21{\cdot}^{57{\cdot}00}$		do.	do.	5	80°	91·9	On making contact the other electrode of					No. 6	burned.
11	$22{\cdot}\frac{01{\cdot}00}{03{\cdot}00}$	120	5	$0{\cdot}585\times10^{-2}$	5	85°	95·3	24·5	6·57	$2{\cdot}93\times10^{-2}$	6·09	6 51	1·009	5·01
12	$22{\cdot}\frac{06{\cdot}00}{08{\cdot}00}$	120	5	$0{\cdot}585\times10^{-2}$	5	85° 15′	95·4	24·5	6·57	$2{\cdot}94\times10^{-2}$	6·11	6·53	1·006	5·01
					Resistance inserted in place of A.									
13	$22{\cdot}\frac{17{\cdot}00}{27{\cdot}00}$	600	5	$0{\cdot}585\times10^{-2}$	720ω	80° 20′	92·1	26·25	7·04	$1{\cdot}22\times10^{-2}$	12·65	13·53	0·520	2·09
14	$22{\cdot}\frac{44{\cdot}30}{46{\cdot}45}$	135	5	$0{\cdot}585\times10^{-2}$	A lamp offering 230ω	78° 00′	90·4	30·80	8·26	$3{\cdot}47\times10^{-2}$	8·09	8·65	0·955	5.93
15	$22\frac{48{\cdot}45}{51{\cdot}00}$	135	5	$0{\cdot}585\times10^{-2}$	do.	78° 00′	90·4	30·65	8·22	$3{\cdot}47\times10^{-2}$	8·09	8·65	0·950	5·93

rent c in absolute measure equivalent to the passage of this quantity Q, we have

$$c = n \pi e k \times 10^{-7} \quad (2)$$

$$\text{and } V_0 = 5{\cdot}43\, n e k t \times 10^{-7} \quad (3)$$

Besides the Cardew voltmeter steady potential indication, a quadrant electrometer, not shown in the diagram, with its needle connected to one pair of quadrants, was employed to measure the potential difference at the voltameter terminals and thus indicate its mean resistance.

The preceding table gives the results of 10 measurements. The volume of the gas is corrected for temperature, but no correction is introduced for the barometric pressure or the tension sustained by the gas in the tube.

The condenser used was adjustable from 0·001 up to 5 microfarads, and from absolute determinations is probably accurate to at least 0·5 per cent.

The last two columns show that

When the density of current per sq. cm. of either electrode was:	the percentage of gas actually generated of that calculated as due was:
1·12	6·2 per cent.
7·9	38 "
30·4 (average)	82·6 "
31·5	78·4 "
46·1 (average)	89·3 "
50·1	100·8 "
62·6 (average)	95·3 "
69·7	98·0 "
141·8	95·6 "

The trials Nos. 13, 14 and 15 were taken without condenser, and with non-inductant resistances in its place. In trial No. 13 this resistance was a length of fine platinum wire offering 720 ohms (hot). In trial Nos. 14 and 15 the resistance was a 96 volt 10 candle-power Edison lamp offering 230 ohms resistance at equivalent illumination. In calculating the current strengths for these three observations, the resistance of the voltameter itself was required. It was measured in two ways: 1st, by means of the quadrant electrometer and the potential differences it indicated on the known resistance and on the voltameter; 2d, by rapidly substituting a non-inductant resistance alternately with the voltameter in the lamp circuit and adjusting this resistance until the illumination was equal in both cases. These two methods concurred in showing the resistance of the voltameter to be 30 ohms, and the maximum resistance it offered through the whole series was 35 ohms.

The table shows that

When the current density per sq. cm. of either electrode was:	The per centage of calculated gas actually liberated was:
20·9	52
59·3	95·3

These results, corroborated by several previous series, go to show that for a rate of alternation of 200 per second and currents of between 0·1 and 0·35 ampères the quantity of gas generated by an alternating current in a voltameter is approximately equal to that generated by an equal continuous current when the mean current density at the surface of the electrode is above 50 ampères per sq. cm. of each; that below that density the quantity of gas developed rapidly diminishes, and that below 1 ampère per sq. cm. soon disappears.

Also that the resistance of a voltameter with very small plates traversed by an alternating current is much less than that it would offer to an equal continuous current. Were this not the case, the resistance of a voltameter for alternating current measurements might for many purposes prove prohibitively great.

ART. XLVII.—*Remarks on the Fauna of the Great Smoky Mountains; with Description of a new species of Red-backed Mouse* (*Evotomys Carolinensis*); by DR. C. HART MERRIAM.

THE fauna of the higher portions of the southern Alleghanies remained almost unknown until 1870, when Prof. E. D. Cope published a paper on the subject.* His bird notes were made so late in the season (in August and September) as to include the beginning of the fall migration and hence are without value so far as concerns the faunal position of the region. Among mammals, he recorded the Red Squirrel and Canada Lynx as inhabiting the higher mountains. A single species of Salamander, the northern *Desmognathus ochrophæus*, was found on the high peaks of the Black Mountains.

The botany of the region received considerable attention, but sixteen years passed after the appearance of Prof. Cope's paper before anything of importance was contributed to our knowledge of its vertebrate fauna. In 1886 Mr. William Brewster published the results of a very brief visit, made at the beginning of the breeding season of birds, to the mountains of western North Carolina (The Auk, iii, 1886, 94-112; 173-179).

* Observations on the Fauna of the Southern Alleghanies. Am. Nat. iv, 1870, pp. 392-402.

On the higher summits Mr. Brewster found breeding in abundance such northern birds as the Winter Wren, Golden-crested Kinglet, Red-bellied Nuthatch, Junco, Solitary Vireo, Olive-sided Flycatcher, Red Crossbill, Pine Linnet, Black-throated Blue Warbler, Blackburnian Warbler, Canada Flycatching Warbler, and several others. He found the region separable into the Canadian, Alleghanian, and Carolinian Faunæ, concerning which he says: "The boundaries of these divisions are determined chiefly by elevation, the Canadian occupying the tops and upper slopes of the higher mountains down to about 4500 feet, the Alleghanian, the mountain sides, higher valleys, and plateaus between 4500 and 2500 feet, and the Carolinian everything below the altitude last named."

Two of the Canadian birds, namely the Junco and the Blue-headed Vireo, were found to be distinguishable from their northern representatives, and hence were subspecifically separated under the names *Junco hyemalis Carolinensis* and *Vireo solitarius alticola*, respectively.

During the summer of 1887 it was my good fortune to visit this very interesting region, in company with Mr. Henry Gannett, Chief Geographer of the U. S. Geological Survey. By Mr. Gannett's kindness I was enabled to accompany him during a buckboard drive of several hundred miles through the Great Smoky Mountains of Tennessee and North Carolina. Although we entered the mountains in the last week of July, migration had already begun, and it was impossible in most cases to discriminate between the resident and migrant birds. In the case of the Junco, however, young were found in all stages of development from the newly hatched nestling to the fully adult bird; and the important fact was ascertained that the local form inhabiting these mountains is specifically distinct from its northern congener. Hence it must stand as *Junco Carolinensis* Brewster.

Of mammals, the Black Bear, Wolf, Deer, Wild Cat, both Red and Gray Foxes, Raccoon, Opossum, and Gray Squirrel still occur in greater or less abundance according to the locality and altitude. The Panther, Porcupine, Pekan, and Varying Hare are unknown. The Chipmunk (*Tamias striatus*) and Woodchuck or Ground Hog (*Arctomys monax*) were common in places in the Alleghanian belt, about half way up the mountains; and the Gray Rabbit (*Lepus sylvaticus*), Red Squirrel (*Sciurus Hudsonius*), and a Red-backed Mouse (*Evotomys*), were common on the higher summits. The latter genus is circumpolar in distribution and has not been previously recorded from any locality south of Massachusetts The present representative of the genus is about double the size of the Canadian *Evotomys Gapperi*, and proves to be distinct from any previously described species. It may be characterized as follows:

Evotomys Carolinensis, sp. nov.

Type 3660, ♀ adult, Merriam Collection. From Roan Mountain, North Carolina (altitude 6000 feet), August 11, 1887. C. H. M.

Description of type.—Size much larger than that of any other known representative of the genus. The following measurements were taken in the flesh: total length 164^{mm}; head and body 111^{mm}; nose to eye 13^{mm}; to center of pupil 15^{mm}; nose to occiput 29^{mm}; tail vertebræ 44^{mm}; pencil 7^{mm}; fore foot 13^{mm}; hind foot 21^{mm}; fore leg 26^{mm}; hind leg 37^{mm}; height of ear from crown 11^{mm}; distance between eyes 9^{mm}; Ears large, suborbicular, prominent; superior margin much incurved but not inflexed; superior root considerably anterior to plane of meatus; antitragus large, its anterior root curving upward in front of meatus and almost reaching the superior root of the auricle. Tail long and slender, tapering from base to tip; not sharply bicolor, though paler below than above. Whiskers black and white, reaching little beyond tips of ears. Hind feet very large, and as broad as in Arctic *rutilus*, though by no means so densely haired; dark, with whitish hairs about the nails; posterior third of soles well haired.

Upper parts dark, with a liberal admixture of black-tipped hairs (agreeing in this respect with specimens of *E. Gapperi* from the upper Red River Valley); dorsal stripe dull chestnut and very broad, spreading out laterally and almost fading insensibly into the fulvous suffusion of the sides (in all the other known forms the dorsal stripe is sharply defined laterally). Sides bister, strongly suffused with light fulvous all the way from the cheeks to the thighs. Color of sides reaching down so far as to seem to encroach on the whitish of the belly, completely enveloping the legs. The belly is strongly washed with ochraceous.

Description of other specimens.—A number of specimens from Highlands, N. C., collected in February, March, and April, agree with the above in all essential respects. The line separating the color of the sides from that of the belly is always distinct and sometimes sharply defined (as in Nos. 2057 ♀, and 2314 ♂). The plumbeous basal portion of the fur shows through on the throat but not on the belly, where it is usually entirely obscured by the whitish apical portion. The ochraceous wash is strongest on the middle of the belly. The tail varies in length in the dry skins from 44^{mm} to 58^{mm}, but these measurements must be regarded as approximate only, owing to possible distortion in preparing the specimens. It is always bicolor with a distinct line of demarcation, though the under surface is never white. The average length of the hind foot in six dry skins is 19·5^{mm}.

Art. XLVIII.—*On a new Thorium Mineral, Auerlite;* by W. E. Hidden and J. B. Mackintosh.

While one of us was about completing a contract for twenty-six tons of zircons, to supply a recent large demand for that mineral, several crystals of the mineral forming the subject of this paper were noticed in the very last shipments from the mine. As the quantity then found was insufficient for a complete chemical and physical examination, the locality was revisited in July last and for five weeks a systematic and laborious search for the mineral *in situ* was carried on. We had already proved it to be a hydrous mineral rich in thoria, with silica and, strangely, a very appreciable quantity of phosphoric acid. Our interest was centered upon its apparent anomalous composition and a series of careful analyses was made by one of us as soon as the necessary material was procured. As the result of the search at the locality not quite 100 grams were found and it became necessary to mine over 200 kilos of zircons to get even this small amount.

It has thus far been found at only two places in Henderson County, North Carolina, namely, at the well-known Freeman mine, on Green River, and on the Price land, three miles southwesterly. At both places it occurs in disintegrated granitic and gneissic rocks intimately associated with crystals of zircons, and it is often seen implanted upon them—as a second or after-growth—in parallel position.

The color on a fractured surface ranges in different crystals from a pale lemon-yellow through various shades of orange to a deep brown-red. The form is distinctly tetragonal, only the unit pyramid and prism being observed, and excepting a tendency to a longer prismatic development, it is much like the common type of zircon found throughout the region. The faces being very rough and uneven, no constant angles could be obtained on any of the material, but they closely approximate to those of zircon.

Fragments of the mineral resemble some varieties of gummite and deweylite, but have a more waxy or rosin-like appearance. It is sub-translucent to opaque, and has a dull yellowish white exterior. It is very brittle and easily crumbled. The hardness varies from 2·5 to 3, some crystals barely scratching cleavage surfaces of calcite. The specific gravity has a wide range, i. e. from 4·422 to 4·766, the dark-orange-red crystals having the highest density.*

* Some of the crystals were much lighter in color, softer and of specific gravity from 3·7 to 3·8. These we propose to examine and report upon later.

The largest mass found measured 1^{cm} through the prism, and it was evidently only part of what had been a long crystal. The bulk of what we collected is in a very fragmentary condition, down to masses and broken crystals of 1^{mm} diameter.

Our analyses have given the following results:

	1.	2.	3.	4.	5.
H_2O }	10·7	----	11·21	----	9·88
CO_2 }				----	1·00
SiO_2	----	9·25	7·64	8·25	
P_2O_5	----	----	7·46	7·59	
ThO_2	----	69·23	70·13		
Fe_2O_3	----	1·42	1·38		
CaO	----	----	0·49		
MgO	----	----	0·29		
Al_2O_3, etc.*	----	----	1·10		
			99·70		

If the amount of CO_2 in analysis number 3 is assumed to be the same as it is in 5, and if we take the amount of H_2O as the difference between the loss on ignition and the CO_2, the ratio of hydrogen equivalents, of bases and acids (assuming the carbonates to be admixed impurity), is nearly 2 : 1 : 2. This gives the formula,

$$ThO_2, \left\{ \begin{matrix} SiO_2 \\ \frac{1}{3}P_2O_5 \end{matrix} \right\} 2H_2O,$$

or a thorite in which part of the silica is replaced by its equivalent in phosphoric acid, when $3SiO_2 = 1P_2O_5$. The ratio of silica to phosphoric acid is variable and is approximately 1 : 1 in hydrogen equivalents; but the P_2O_5 tends to be in excess.

We have considered it possible that this mineral is a mixture of a hydrated thorium phosphate with a hydrated thorium silicate, in some respects analogous to the occurrence of zirconium-silicate (zircon) in parallel position with yttrium-phosphate (xenotime),† although there is nothing in the appearance to suggest this—the mineral seeming to be perfectly homogeneous, except on the exposed surfaces. It is more probable, however, that we have here an example of a partial replacement of silica by phosphoric acid, which fact has not yet, to our knowledge, been noticed in the literature of Mineralogy; unless we should so regard the small proportion of P_2O_5 (4·17) which Eakins‡ observed in the xanthitane (altered titanite) from the same locality.

This occurrence of a thorium phosphate is the first instance of such a compound existing in nature and seems to have a

* Including other oxides with traces of thoria.

† This Journal. Nov., 1888, p. 380.

‡ This Journal, vol. xxxv, p. 418, May, 1888.

direct bearing upon the presence of thorium in monazite, and we believe that the idea that thorium is included in monazite as thorite—mechanically intermixed—should be modified in so much that the thoria should be considered as partially present as a phosphate and the cerium earths partially present as silicates.

This mineral is readily soluble in hydrochloric acid, leaving a residue of gelatinous silica; after ignition it becomes insoluble. Thorium phosphate is generally regarded as a very insoluble compound, but the ready solubility of this mineral seems to disprove that opinion.

It is infusible and upon strong ignition becomes dull-brown and on cooling, orange again.

Thorite crystals having the form of zircon have been described by Zschau;* and Nordenskiöld,† and later Brögger,‡ have expressed the opinion that the mineral known as thorite is a pseudomorph after an original thorium silicate analogous to zircon in composition. This view is confirmed by the fact that this new mineral occurs intimately associated with and implanted upon perfectly unaltered zircon.

As this mineral was found while mining the very large quantity of zircons necessary to supply the demand caused by the invention of the system of incandescent gas-lighting of Dr. Carl Auer von Welsbach, we propose to name it *Auerlite* in his honor.

ART. XLIX.—*On a new Sodium sulphato-chloride, Sulphohalite;* by W. E. HIDDEN and J. B. MACKINTOSH.

IT was in the mineral collection of Mr. Clarence S. Bement, of Philadelphia, and along with a series of remarkable crystals of hanksite that one of us first noticed the mineral here described; it was recognized by a few simple tests to be a new species. It had been considered, at the locality, to be "a rhombohedral type of hanksite" and the misinterpreted form of its crystals —implanted as they were upon hanksite—was the reason for that opinion. A few measurements with a hand goniometer soon showed them to belong to the isometric system and the form to be the simple rhombic dodecahedron. The mineral occurs only as crystals, which are in form and sharpness of angle, all that could be desired. It is transparent with a faint greenish-yellow color. The crystal faces are smooth and well polished and vary in size from $\frac{1}{2}$ to $2\frac{1}{2}^{cm}$ diameter. The spe-

* This Journal, II, xxvi, 359; see also Dana's Syst. Min., Ed. 1868, p. 413.
† Geol. För. Förh., iii, 226, 1876; see also App. III, Dana's Min., p. 121.
‡ Ibid, ix, 258, 1887.

cific gravity, as taken in naphtha, is 2·489. Their hardness is about 3·5. The mineral is very slowly soluble in water and remains unaltered in a moderately dry atmosphere. A careful analysis by one of us on amounts of 100 and 120 milligrams yielded the following results:—

Cl	13·12 per cent.
SO_3	42·484 "
Na_2CO_3	1·77 "

Calculating the chlorine and sulphur as combined with sodium only, we get

$NaCl_2$	21·624
Na_2SO_4	75·411
Na_2CO_3	1·77
	98·805

The formula figures out exactly, if the loss and the Na_2CO_3 are estimated with and as Na_2SO_4; i. e., if the loss is Na_2SO_4 and we consider the Na_2CO_3 as replacing a little Na_2SO_4.

The formula can then be expressed thus: $Na_2(\frac{3}{4}SO_4, \frac{1}{4}Cl_2)$ or $3Na_2SO_4$, $2NaCl$. Excepting the very rare mineral connellite, from Cornwall, England, which is believed to be a cupreous sulphato-chloride (crystallizing in the hexagonal system), we know of no other species related in composition.

We learn from Dr. A. E. Foote, in whose stock of Borax Lake minerals we were fortunate enough to find the single specimen of the mineral used in this examination—that he had visited the locality this past summer and that about one month before his arrival a company had been testing the immense alkaline deposit of Borax Lake (San Bernardino County, California), and had drilled an eight inch hole to a depth of over 100 feet. At a depth of 35 feet a small cavity was discovered from which there were pumped out through the drill hole the mineral here announced, with some very remarkable crystals of hanksite.

But three examples are at present known to us, and two of these of remarkable beauty, are in the Bement collection, the other specimen (a crystal about one inch thick, having long prismatic hanksites implanted upon it), is the one, upon a part of which, this analysis was made.

It is a matter of interest to note that this mineral, with its anomalous formula, should occur with and be associated upon another mineral, hanksite, having a like strange composition.

We propose for this new mineral the name *sulphohalite* as suggesting its remarkable composition.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Vapor-density of Aluminum chloride.*—The experiments of Nilson and Pettersson (Zeitschr. phys. Chem., i, 459) seemed to show that aluminum chloride when heated in an atmosphere of carbon dioxide gave, at a temperature of about 835°, a vapor-density corresponding to the formula $AlCl_3$; and this without evidence of decomposition, although above 935° the platinum vessel was attacked. Friedel and Crafts have pointed out that exact results are obtained with V. Meyer's method (which was the one used by Nilson and Pettersson) only when there is no diffusion of the vapor into the air of the apparatus. And they have therefore re-determined the vapor-density of aluminum chloride by the method of Dumas, taking great care to obtain and to maintain the substance perfectly anhydrous. The aluminum chloride was obtained by sublimation in large, colorless and comparatively non-hygroscopic crystals, which though volatilizing directly without fusion at ordinary pressures, melt at about 186° under a pressure of 2·5 atmospheres. The vapor-pressure of this substance was found to be 252·1 mm. at 167·8°; 311·4 mm. at 170·4°; 316·5 mm. at 171·9°; 430·7 mm. at 175·7°; 755·4 mm. at 182·7°; 1793·4 mm. at 204·2°; 2016·1 at 207·5°; and 2277·5 mm. at 213·0°. The temperatures at which the vapor-densities were determined were 218°, 263°, 306°, 357°, 390°, 398°, 400°, 415°, 429° and 433°; and the results agreed closely with the density 9·24, the value corresponding to the formula Al_2Cl_6; thus confirming the earlier results of Deville and Troost. Since the lowest temperature at which Nilson and Pettersson operated was 440°, it may be that the lower values obtained by them are due to a dissociation of the molecule Al_2Cl_6 into $(AlCl_3)_2$ analogous to that of iodine, or into Al_2Cl_4 and Cl_2 as in the case of ferric chloride. The authors' experiments prove, however, that aluminum chloride becomes a perfect gas at 218°, or 35 degrees above its boiling point; and that the density of this vapor is sensibly the same up to 400°. Hence they conclude that the formula of this substance is Al_2Cl_6; a conclusion in agreement with the determinations of Louise and de Roux of the vapor-densities of aluminum methide and aluminum ethide.—*C. R.*, cvi, 1764; *J. Chem. Soc.*, liv, 1040, Oct., 1888. G. F. B.

2. *On Freezing mixtures containing solid Carbon dioxide.*—Cailletet and Colardeau have determined the temperature of solid carbon dioxide, alone as well as when mixed with other suitable substances, in air and in vacuo. For this purpose they used a thermo-electric couple which had been calibrated by comparison with a hydrogen thermometer. The carbon dioxide alone, either compressed or porous, when exposed to the air, had a temperature −60° and when in a vacuum over potassium hydrate,

−76°. When mixed with ether, the dioxide had a temperature of −77° in air and of −103° in a vacuum. Liquid carbon dioxide solidifies in such a mixture. On the addition of the solid dioxide to the ether it at first dissolves, and after a time bubbles of gas are evolved. On continuing to add the dioxide the liquid becomes saturated and opalescent, the temperature falling until the instant of saturation is reached, when no farther fall of temperature occurs on adding more dioxide. Hence it would appear that the effect of the ether is due simply to its dissolving the dioxide. Other solvents may be used. Methyl chloride gives −82°; sulphurous oxide −82°; amyl acetate −78°; phosphorous chloride −76°; alcohol −72°; and ethylene chloride −60°. When the mixture with methyl chloride or sulphurous oxide is placed in a vacuum the temperature is lowered to a point at which the solvent solidifies and then no farther reduction takes place. The temperature thus obtained with methyl chloride is −106°. A mixture with chloroform solidified at the ordinary pressure at −77°.—*C. R.*, cvi, 1631; *J. Chem. Soc.*, liv, 1025, Oct., 1888. G. F. B.

3. *On the Determination of the Heat of Combustion of Coal.*—SCHEURER-KESTNER has analyzed and has also determined the heat of combustion of twenty-one samples of coal from the north of France, by direct experiment, and has compared the results with those calculated from the composition of the coals. The coal in small fragments was burned in a rapid current of moist oxygen in a Favre and Silbermann's calorimeter; the results being corrected by subtracting from the heat of combustion actually observed with the moist gas, and consequently with complete condensation of the water formed, the number of calories equivalent to this condensation. Since the combustion of hydrogen gives 34,500 or 29,088 calories according as the water formed is condensed or is in the state of vapor, the difference, or 5413 calories, multiplied by the content of the coal in hydrogen, represents the number of calories to be subtracted from the observed heat of combustion. The values of the heats of combustion actually obtained do not agree with the values calculated from the composition, being sometimes greater than the sum of the heats of combustion of the constituents and sometimes less. Cornut has proposed a formula for calculation based on the assumption that while solid carbon evolves 8080 calories, the heat of combustion of carbon in the state of vapor is 11,214 calories. But the calculations founded on this formula of Cornut, while giving results somewhat closer to those actually observed in some cases, are in other cases so far from the truth as to destroy confidence in it. The formula of Dulong is even less satisfactory. No explanation is offered as to the cause of these discrepant results, but they seem to establish the important fact that coal has been formed at least in part by endothermic reactions. The general results give between 8340 and 9257 calories, the mean values lying between 8400 and 8800 calories.—*Ann. Chim. Phys.*, VI, xv, 262, Oct., 1888. *J. Chem. Soc.*, liv, 774, Aug., 1888. G. F. B.

4. *On the Wave-length of the Double red line in the spectrum of Potassium.*—By means of a Rutherfurd grating ruled on glass, and the electric arc, DESLANDRES has succeeded in measuring the wave-length of the two components of the double potassium line in the red, known as Kα. He finds for the stronger of the two lines the value 7663·0 ten-millionths of a millimeter, and for the weaker line the value 7696·3 ten-millionths; the value for D being taken at 5888·9. This agrees with the value 7680·0 found by Mascart for the group, that of D being 5888·0.—*C. R.*, cvi, 739; *J. Chem. Soc.*, liv, 637, July, 1888. G. F. B.

5. *Electrical discharges in gases and flames.*—The observation of Hertz upon the effect of the ultra violet rays upon electrical discharges has awakened wide spread interest in Germany. Among other workers, E. WIEDEMANN and H. EBERT have repeated and confirmed Hertz's results. They have also investigated the effect of ultra violet rays upon electrical discharges which are taken in various media. The source of light was a Schuckert's electric arc light. It was found that the effect of the ultra violet rays was greatest when the electrodes between which the electrical discharge passed were of platinum. A telephone was intercalated in the circuit and the character of the discharge when the electrodes were in the violet rays and when they were not could be readily distinguished. A glass plate which allowed the violet rays to pass, but absorbed the ultra violet, immediately caused the phenomenon to disappear; thus it was shown that the ultra violet rays alone were effective. The effect varied with the character of the electrodes, being greatest with platinum. And then in the following order: zinc, copper, iron, aluminum, palladium, silver. When the discharge was taken from the surface of a liquid, the greatest effect was always obtained when the liquid was capable of absorbing the ultra violet rays. The authors believe that the phenomena can be attributed to the selective absorption for ultra violet rays of the surfaces between which the electrical discharges pass. The short wave-lengths set the molecules on these surfaces into vibration and thus aid the disruptive effect which is seen in the discharge. The phenomenon was also investigated in Geissler tubes and with low pressures. When the electrical discharge grew rich in ultra violet rays, the effects of similiar rays from the arc lamp were less noticeable. The discharge was also taken between points placed in flames which were colored by various salts. These salts changed the character of the discharge greatly, as was evidenced by the noise in a telephone connected with one of the electrodes. The greatest effect was obtained from potash and from the magnesium salts, thus affording another instance of the effect of ultra violet rays affecting the electrodes by selective absorption.—*Ann. der Physik und Chemie*, No. 10, 1888, pp. 209–264. J. T.

6. *Electrodynamic effect produced by the movement of a dielectric in an electrical field.*—W. C. RÖNTGEN revolved a glass or vulcanite disc between two horizontal plates of a condenser, one

of which was connected with the earth, the other with the source of electricity. Above the upper condenser plate was hung a very sensitive magnetic system. The direction of the magnetic needles was perpendicular to a radius of the revolving disc, and their middle point was near the edge of the disc. The deviation of this system was measured by a mirror, telescope and scale. The author concludes, after discussing the relation of the effects observed to those obtained by Rowland and by others, that a small electrodynamic effect can be noticed, when a dielectric is moved in a homogeneous electrical field.—*Ann. der Physik und Chemie*, No. 10, 1888, pp. 264–270. J. T.

7. *Light and Electricity.*—Lord Rayleigh (B. A., 1888) has been endeavoring to discover if an electric current flowing through an electrolyte causes the velocity of light to vary through the liquid. He experimented with dilute sulphuric acid. The result was negative within the range of the experiment, which was extremely delicate. In H_2SO_4 diluted, one ampère per square centimeter does not alter the velocity of light by one part in thirteen millions, or by fifteen meters per second.—*Nature*, Oct. 4, 1888, p. 555. J. T.

8. *The energy stored in permanent strains;* by C. Barus. (Communicated). — Apropos of certain strain experiments of Wassmuth, an account of which has just reached me in the Beiblätter (No. 9, p. 648, 1888), I desire to advert to somewhat similar results which I have in hand. I brought a measured amount of work to bear on soft metallic wires, and by deducting from this the energy thermally dissipated (measured in a way essentially like that of Wassmuth), I was able to express definitely the energy potentialized in effecting given changes of molecular configuration. In this respect my work and purposes are distinct from Wassmuth's. Necessarily operating on *soft* metal, I find that the values for the maxima of energy stored under given conditions differ so largely in different metals, that I am justified in treating them as molecular data of importance.

II. Geology and Mineralogy.

1. *International Congress of Geology.*—The members of the "Provisional Committee" appointed at the Congress in London, with reference to preparations for the next meeting of the Congress at Philadelphia, whose names are mentioned on page 389, met at New Haven, on Thursday, the 15th of November. All were present except Dr. T. Sterry Hunt. By vote twenty-four members of the permanent or organizing committee were appointed, as follows: C. A. Ashburner, J. C. Branner, T. C. Chamberlin, G. H. Cook, J. D. Dana, W. M. Davis, C. E. Dutton, G. K. Gilbert, James Hall, A. Heilprin, C. H. Hitchcock, Joseph LeConte, J. Leidy, J. P. Lesley, O. C. Marsh, J. S. Newberry, J. W. Powell, J. R. Procter, N. S. Shaler, J. J. Stevenson, C. D. Walcott, R. P. Whitfield, H. S. Williams,

Alexander Winchell. The committee has power to add to its number. Dr. J. S. Newberry was appointed temporary chairman. With this action, the duties of the provisional committee ended. The first meeting of the permanent committee will be held in Washington in the month of April.

2. *American Report to the International Congress of Geologists at the meeting in London commencing September* 17, 1888.—This Report, as the title-page states, is made up of "Reports of the American Sub-committees appointed by the American Committee from its own members, assisted by associates, and is "printed by order of the Committee. Editor, Persifor Frazer." It contains valuable papers on American stratigraphical geology prepared chiefly by the Chairmen or "Reporters" of several Sub-committees, and interesting reading as the personal opinions on various questions, which were gathered in by the assiduous Secretary and some of the "Reporters" through epistolary canvassing. But on controverted points it is a "majority" report of the Committee and of its several Sub-committees, and a minority report as regards American geologists. The canvassing gathered opinions, but not the final views which free discussion among the geologists of the country would have evoked. Moreover the methods of the Committee tended to suppress discussion even in the Sub-committees.

The Preface of the published Report states that "all geologists were invited to meet the American Committee in Albany during its session there (April 6th, 1887), in order to aid it in arriving at a correct view of American opinion." Such a call was published in volume xxxiii of this Journal (1887); but the notice of the next meeting at Philadelphia, communicated to the same volume by the Secretary, shows that it failed of the object announced.

At the only meeting attended by the writer, that of January last at New Haven—not then *resuming* active membership, as the published Report states in its Preface, but taking my first experience in membership after receiving my first notice that I was a member, the chairman,—Dr. T. Sterry Hunt, opened the session in the morning by announcing that five-minute speeches only would be allowed in discussions, and no replies, thus showing at the outset that full and fair consideration of questions was not to be permitted.

During the day the reports of some of the Sub-committees were read and passed, but no opportunity was allowed for the discussion of any of the propositions to the International Congress which they contained. Before the meeting closed, a vote was passed by which "the *Reporters of the Sub-committees* respectively were made sole and final judges of the manner in which communications received from other geologists should be used." At the same time "the reports on the Archæan, Devonic, Carbonic, Mesozoic and marine Cenozoic" were declared adopted and ready for printing, and those "on the Lower Paleozoic and In-

terior Cenozoic were referred back to the Sub-committees making them," but not for any changes, except such as the "Reporters" might make. I was not aware in January that such votes had passed, nor that any of the reports were beyond amendment, and learned of it first through a letter from the Secretary in March. Major Powell addressed a communication on the subject, dated March 27th, to Professor Hall, protesting against such a ruling, and in opposition to other actions of the Committee, and at the same time resigned his connection with it. For like reasons, I did not attend the April meeting.

Finally, at the April meeting, it was voted that no copies of the published report should be delivered before September 17th, or in other words that the printed report with its final additions should be kept from the members of the Committee until the day of meeting of the Congress in London. And so it was: on the 17th, punctually, the first copies reached me in New Haven.

Under such partisan management, the conclusions in the printed reports of the several Sub-committees were not likely to represent fairly American geological opinions. It is true that in connection with each of them a large display is made of the names of the members of the Sub-committees, and of *all* of them in each case, as if they were alike responsible for the contents, and as if the members had met, at least once, and consulted together, read the last emendations and signed the document. But in this it gives a very wrong impression. My name is on two of the Sub-committees, but has no right to a place on either, although I gave assent to the request; for I was informed of no meeting of the Sub-committee for consultation, and joined in none, and gave my signature to nothing except the letters which I, like many others not of the Committees, wrote in answer to questions. In fact, as above shown, changes after the January meeting were made impossible except by the Reporter. I received a proof of the report on the Lower Paleozoic, but returned it without any words of approval and only a few on the Taconic question. Further, this report, as finally published, contains what was not in that proof; it is decidedly the report of the Reporter, who had been made the "final judge of the manner in which communications received should be used," not the Committee's report; and the same is true in some other cases. The views of Mr. C. D. Walcott are unfairly presented with great injustice to him, although he stands as an associate member of the Sub-committee, responsible as much as the rest for its Report.

Five hundred copies of the Report of the American Committee were published. It is now in the hands of the Secretary of the London meeting of the Congress, awaiting a second publication as if the expression of the views of the majority of American geologists. Its right to appear in the volume of Proceedings of the Congress for 1888 should be seriously considered if it is not already too late. J. D. D.

3. *On the Volcanic Phenomena of the Eruption of Krakatoa, and on the nature and distribution of the Volcanic Materials;* by J. W. JUDD, F.R.S., Pres. Geol. Soc. 56 pp. 4to, with 6 plates. From the Report of the Royal Society Commission.—The great eruption of Krakatoa, its results, and the character of its ejected materials, are here ably discussed by Professor Judd, with illustrating plates, maps, and wood-cuts. After sketching the earlier history of the volcano, the author comes to the precursor events of the eruption of 1883, which began May 20th, and then to the culmination in the paroxysmal eruption of August 26th and 27th. Views and maps show the changes that took place at the time in the island and in the seas about it. The cone of Krakatoa was left between 2,000 and 3,000 feet high, and the crater more than 1,000 feet deep.

Professor Judd's explanation of the eruption is this: that the interruption of the regular escape of vapors and ejections that was consequent on the chilling of the surface of the liquid lava by inrushes of sea-water caused a check and then a rally of the pent-up force of gases seeking escape; that the catastrophic outburst was a direct consequence of this "check and rally" of the subterranean forces.

The rocks of the cone and the ejected materials are described in detail, and illustrated by microscopic sections. The rock about the crater is enstatite-dacite or enstatite-andesite. There are also black porphyritic pitchstones. The small cone of Rakata, at the base of Krakatoa, consists of basaltic lavas, which are in part chrysolitic. The formation of the ejected pumice from the pitchstone, on which the author had previously thrown much light, is the subject of further remarks and explanations. He speaks of the glass as being in a state of strain, as is proved by its depolarizing light, and this is mentioned as the cause of its extreme brittleness, in consequence of which it easily crumbles to the finest dust. The rocks are shown to have varied much in liquidity, although having little difference in mineral constitution; and this is attributed to the amount of water they contain. Professor Judd further observes that with water present and therefore a low fusion point, there is less chance of devitrification in a liquid lava; whereas without water and a consequent high fusion point, crystallization of minerals or lapidification is likely to take place in the mass as cooling makes progress; and thus from lavas of the same constitution, under the one difference of amount of water, rocks of very unlike aspect may result.

4. *Microscopical Physiography of the Rock-making Minerals and aid to the microscopical study of rocks*, by H. ROSENBUSCH. Translated and abridged for use in schools and colleges by JOSEPH P. IDDINGS. 333 pp. 8vo, with 26 plates of microphotographs, New York, 1888. (John Wiley & Sons). The thanks of our English-speaking students of Petrography are due to Mr. Iddings for the excellent manner in which he has presented to them the work of Prof. Rosenbusch. The value of this work is much too

well known to make it need commendation here, and the English form that it has now taken is all the more serviceable because of the wise abridgment which it has received, while all that is essential has been retained. The translation is faithful and accurate but sometimes follows the German idiom more closely than is necessary. We may now hope to have instruction in this subject extended among a much larger number of students than has hitherto been possible. The publishers deserve praise for the good appearance which the volume presents and especially for their enterprise in securing copies of the beautiful plates which form so important a part of the German work.

5. *Phenacite in New England*, by GEO. F. KUNZ. (Communicated).—In the September number of this Journal, page 222, the finding of phenacite and topaz near Stoneham, Me., is announced; the locality should have been on Bald Mountain, North Chatham, N. H. Both towns are on the Maine and New Hampshire state line, hence the error now corrected. Another pocket has been found, so that in all over fifty crystals of phenacite and topaz have been procured.

III. BOTANY.

1. *Color-granules in flowers and fruits.*—With the improved optical appliances and better staining agents employed in recent years the coloring matters of plants have received renewed attention. The last contribution on the subject is a paper by COURCHET, [Ann. Sc. nat. sér. VII, pp. 263–374, pl. 6] which confirms certain statements made, with some hesitation, in a review published in this Journal during the current year. Courchet's work appears to have been conducted in a careful manner under the supervision of Flahault at Montpelier, and with abundant material. It is therefore satisfactory to note that it strengthens in all essential particulars the position taken by Schimper, to which reference will soon be made. In view of the importance and the general interest of the subject, it seems proper to give an account of the additions which Courchet has made to our knowledge, and to re-examine briefly the whole matter.

The earlier investigators made out clearly that the coloring substances in leaves, flowers and fruits were of the following kinds: (1) colored cell-sap; (2) protoplasmic bodies or color-granules, containing pigments of various kinds; (3) crystals; (4) pseudo-crystalline forms and amorphous masses. Attempts were made by *Unger* (1846), *Mohl* (1851), *Trécul* (1858), and *Weiss* (1864), to determine the morphology of these structures, but with comparatively little success. Trécul described the facts with accuracy, and for the most part with clearness, but he gave an undue degree of prominence to his theory of vesicular formations, thus diminishing the value of his work. Weiss stated that the color-granules appeared to arise in two ways, (1) by free formation from the general mass of protoplasm, and (2) by the

modification of chlorophyll-granules. In 1872 *Kraus* added some observations regarding ordinary spindle-shaped forms, and stated that they appeared to come from the breaking down of the protein color-granules, but this view was opposed by the fact that these bodies occur even in some very young parts. *Millardet* (1876) by an examination of the coloring matters in the fruit of the tomato, made out some of the relations existing in many cases between chlorophyll-grains and color-granules. It was shown by him that these could change into one another under certain circumstances, and that they possibly had a common origin. This link was partly supplied in 1880, by *Schimper*, who announced the discovery in certain cells containing starch, of colorless granules, which had the function of collecting from the nutrient cell-sap the materials for the construction of starch grains. These bodies were termed by him starch-formers. After pointing out their occurrence and indicating the precautions necessary for their detection, he hints that they have close relations to the other living proteid granules in the vegetable cell. Soon after this, several investigators took the subject up, notably *Meyer*, while Schimper himself made a most important advance. This step consisted in coördinating all the granular living proteid granules, holding that color-granules and chlorophyll-granules are derived from the colorless granules found in the cells at the growing points of plants. For these bodies the common appellation of plastids or plasts was proposed, with the distinctive prefixes, leuco-, chloro-, and chromo-. About this time, or a little before, Van Tieghem suggested the term leucites for the same thing. Although Schimper's terms have been generally adopted, Courchet prefers Van Tieghem's. Schimper teaches that these plasts arise from pre-existing plasts, and that they assume the special form of leucoplasts, chloroplasts, or chromoplasts, according to the office of the part and the conditions under which they are developed. The morphological interest attaching to the organs of a plant is greatly heightened, when it is seen that in the cells themselves which constitute them, there are adaptations not merely in form but in the granular differentiations of the living matter. Just as a foliar expansion can be turned to account by the plant in many different ways, as a foliage-leaf, as a tendril, as a fly-trap, as a thorn, or as a pitcher, so can these simple proteid granules undergo modifications adapting them to the most diverse kinds of work. From the point of view of evolution the subject is of great importance, clearing up some serious difficulties in the way of explaining the adaptation of colors in flowers and fruits to the visits of insects and of birds. The diversified shapes of foliar and floral organs have been rather easier to understand than the marvellous range of useful colors in these parts of the plant, but it is now apparent that all of them may arise from the very simplest starting point common to all.

In all important features, Courchet confirms Schimper's views, and they may be considered as in the main firmly established.

The matter is one of those, which, like the continuity of protoplasm throughout the plant, commands from its coördinating power general acceptance, and should therefore be most carefully examined and reëxamined to ensure complete accuracy of details.

Courchet's special results may be briefly stated as follows:—Chromoplasts are always formed at the expense of chloroplasts or leucoplasts and can give rise at their periphery to crystals or crystalloids. The pigment is produced in many ways, and assumes very diverse characters. The form of the pigment masses is not related to the color, but depends upon its chemical constitution and the matters with which they are combined. Blue, violet and rose tints are generally due to colored cell-sap, although blue pigments are sometimes in the form of crystals or granules which have no relation to the plastids. The orange tints are chiefly due to crystals, or solid masses, and the same is true of most of the yellow tints. Chromoplasts always have a protein stroma combined with the pigment, which latter may be in such fine particles as to give an homogeneous appearance to the whole. The pigment may crystallize out of the granule, and present an appearance as if it is quite independent of it, and it may assume the most diversified shapes. The pigment may, under certain conditions, behave exactly like coloring matters found in other parts of the plant, but whether these matters are produced from the green pigment of the chloroplasts or from derivatives built up in those granules it is, as yet, impossible to determine. It is easy, however, to distinguish two types of coloring matters in the plastids: (1) yellow, always amorphous, much more soluble in alcohol than in chloroform and ether, turning blue with concentrated sulphuric acid, taking on an intermediate green tinge; (2) orange, more soluble in ether and chloroform than in alcohol, turning blue with concentrated sulphuric acid, taking on first a violet-red or violet tinge.

Coloring matters in cell-sap do not as a rule turn blue under the action of concentrated sulphuric acid. G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *Note on the work of the American Eclipse Expedition to Japan*, 1887; by David P. Todd, Astronomer in charge.—In my preliminary report it was stated that the volunteer observers, working under instructions prepared by me and printed and distributed through the coöperation of the Japanese government, had been moderately successful. Just how successful, it was not possible to ascertain before leaving Japan. But within a few weeks, I have received through our Department of State, a large MS. volume of about seventy drawings of the corona. These are now in process of discussion on a novel system, and are likely to make a trusty contribution to optical coronagraphy.

Also, through the same channel, came a valuable series of observations of the simple duration of total eclipse, at points just

inside the limits of the shadow-path. Of these there are about one hundred independent determinations. When the geographic positions of the observers have been accurately determined, and the observations fully reduced, accurate corrections to the lunar orbit-elements will result, for the epoch in question. The work of the main party in my charge, at Shirakawa, concludes rather less favorably than I had expected, clouds having interfered to such an extent that less than half of the pictures taken with the photo-heliograph are measurable.

The foregoing results of the volunteer work comprise thus the most important astronomical contribution of the Japan Expedition; and are so encouraging that, under the auspices of the Bache trustees, I have taken steps necessary to secure like observations in our western states and British America during the eclipse of the 1st of January next.

But the total outcome of the Japan Expedition fortunately comprises important work besides astronomy. Dr. Holland, who at his own charges accompanied the expedition as naturalist, has enumerated the bulk of his collections, botanical and entomological, in the preliminary report. Under his direction, the final discussion of this valuable material is rapidly progressing. On the present plan, four papers will result: (*a*) list of the phænogamous plants collected by the Expedition; (*b*) list of *Coleoptera* collected by the Expedition, together with descriptions of some apparently new species (with the colaboration of Mr. C. O. Waterhouse of the British Museum); (*c*) list of the *Macrolepidoptera* collected by the Expedition, together with descriptions of new species and notes upon their habits; (*d*) a monograph of the *deltoid* and *pyralid* moths of Japan.

Of these the most significant is the last, in which Dr. Holland will include a full discussion of the unique and extensive collections of the late Mr. Pryer of Yokohama, the result of his labors during a long series of years. Some months are necessary to complete this monograph.

2. *National Academy of Sciences.*—The following papers were entered to be read at the November Meeting, 1888, in New Haven.

E. S. HOLDEN: The Lunar Eclipse, July 22, 1888.

LEWIS BOSS: The Zone Undertaking of the Astronomische Gesellschaft.

ELIAS LOOMIS: The Rain-fall of the North Atlantic Ocean.

W. H. BREWER: A finished Breed of Horses.

WOLCOTT GIBBS and HOBART EMORY HARE: A Systematic Study of the action of definitely related Chemical Compounds upon Animals.

J. S. NEWBERRY: The Cretaceous Flora of North America; On the Zoological Relations of some Paleozoic Fishes.

HENRY F. OSBORN: The Evolution of the Mammalian Molar Teeth to and from the Tritubercular Type.

L. A. LEE: Some scientific results of the Albatross Expedition from Washington to San Francisco.

A. A. MICHELSON and E. W. MORLEY: Some measurements of relative Wavelengths.

E. S. DANA: A new mineral from Maine.

C. H. F. PETERS: Remarks on the expression of the Law of Attraction in the Stellar Systems.
A. HALL: Note on the Satellite of Neptune.
G. K. GILBERT: The Problem of Soaring Birds.
J. W. POWELL: The Laws of Corrasion.

3. *Note to Article VIII, in this volume, by the Author.*—In mentioning the dredging at Sandwich, in the July number of this Journal (p. 56), I did not expect to give the subject further attention. I have since become satisfied, after visits to the place named and extended inquiry, that no Tertiary beds have been opened there. The supposed "find" has proved a disappointment. There is too little information about it available to justify attaching any importance to it. The borings made along the line of the proposed canal give no reason to expect that fossiliferous deposits will be touched hereafter in the progress of the work. W. W. DODGE.

4. *Tuckerman Memorial Library.*—The large collection of books and papers relating to Lichens, made by the late Prof. Edward Tuckerman, has been presented by Mrs. Tuckerman, in accordance with his own wish, to Amherst College Library. It is desired to make this "Tuckerman Memorial Library" as complete as possible and the librarian, Mr. William I. Fletcher, invites contributions in money or in material to this end. The money contributed will be kept as a fund of which only the income will be employed in making additions to the collection, or in making repairs to the binding. The sum of $1000 would probably suffice as such a fund.

A Manual of the Vertebrate Animals of the Northern United States, by David Starr Jordan, President of the University of Indiana, 5th edit., entirely rewritten and much enlarged, 376 pp., 12mo, Chicago, 1888. (A. McClurg & Co.) In this new edition of the Manual all marine species are included; the geographical limits have been extended so as to include Canada, Minnesota, Iowa and Missouri; and the arrangement has been changed, and other improvements introduced.

Catalogue of Fossil Reptilia and Amphibia of the British Museum. Part I, containing the Orders Ornithosauria, Crocodilia, Dinosauria, Squamata, Rhynchocephalia and Proterosauria, by Richard Lyddeker, B.A., F.G.S., etc. 310 pp. 8vo. London, 1888.

Cincinnati Observatory. Zone Catalogue of 4050 stars for the epoch of 1885, by J. G. Porter, astronomer. Cincinnati, 1887.

Old and New Astronomy, by R. A. Proctor. (Longmans, Green & Co., London and New York.)

Transactions of the American Philosopical Society, Vol. XVI, Part II, contains papers by E. D. Cope on the intercentrum of terrestrial vertebrata, systematic catalogue of the Permian vertebrata of N. America, Synopsis of the Vertebrate Fauna of the Puerco series, the shoulder, girdle and extremities of Eryops, and by H. C. DeS. Abbot, on a chemical study of *Yucca angustifolia*.

Centennial volume of the Memoirs of the American Academy of Arts and Sciences, Vol. XI, Part VI, No. vii. 200 pp. 4to. Occupied with a Memoir of Daniel Treadwell by Morrill Wyman, M.D.

Die Geoideformationen der Eiszeit. von Erich von Drygalski, Dr. Phil. (Ges. d. Erdk. Berlin, xxii, 3, 4,) Berlin, 1887.

Annotated Catalogue of the species of Porites and Synaræa in the U. S. National Museum, with figures, and a description of a new species, by Richard Rathbun, Proc. U. S. Nat. Mus., 1887.

5. *Communication on the American Report of the International Congress of Geologists*, by J. W. POWELL, Director of the U. S. Geological Survey; addressed to the Editor of this Journal under date of Washington, D. C., Nov. 23, 1888.*—The American report presented to the International Congress of Geologists at the meeting in London commencing September 17, 1888, has been received, and I find that my name is attached to it in several places in such a manner that I am made to appear as one of the parties responsible for its preparation and agreeing to it. This is an unfair and improper use of my name. I was for much of the time a member of the committee, but when it became manifest that some of its members were determined to submit a report in general character similar to the one finally submitted, I resigned from the committee, preferring so to do rather than prepare a dissenting report. Without entering into detail, lest this communication be made very long, I beg to present my general reasons for not wishing to be considered as in any way subscribing to the report.

The subject matter of the report is not of such a nature that a deliberative body can properly determine it by vote. Facts of observation, and generalizations therefrom, are proper subjects for discussion, but they should not be submitted to decision by vote. In my judgment this principle is fundamental.

At some of the meetings I was represented by a delegate; and at some of the meetings I was present. Through my representative and personally myself, I endeavored to induce the committee to consider questions of geologic technics, such as a color scheme and a fundamental taxonomic time scheme necessary to the use of a color scheme; and I endeavored to have principles of geologic nomenclature formulated, etc. I protested, in season, and perhaps out of season, against pursuing such a course as to make the committee a debating club on geologic theories and on the verity of geologic discoveries.

The assembling of a large number of geologists from various portions of the world, all more or less engaged in active research, furnishes a valuable opportunity for the presentation of papers, for the interchange of opinions, and for the enlargement of the scientific horizon of the several members. The questions that arise in this manner are to be decided ultimately only by the light of science, and no weight should be given to any man's statement or generalization other than that inherent in the facts themselves. For a deliberative body to determine or settle any such question, or in any way to make authoritative annunciation of facts and principles, is at variance with sound scientific procedure and wholly vicious.

On the other hand, geologic language is conventional, as all language is conventional, and all geologic conventions, whether

* Received too late for earlier insertion.—EDS.

they are in words, in colors, or in graphic forms, can be established by agreement with propriety, and perhaps with advantage to the science.

There is no body of men so wise or so powerful that it can establish the science of geology by authority, and it is pretentious and unseemly to make the attempt; and to authoritatively announce a fact or generalization in science and ask its acceptance is an absurdity. Any number or body of geologists may properly agree to use a common system of representation, and may properly recommend others to use the same.

In view of these considerations, I urged upon the committee questions of conventions, as I greatly desired that the American committee should formulate American opinions upon these subjects.

The papers which appear in the report were not presented to the committee in a finished form, while I was present, but most of them merely in abstract, and the reporters finally published what they severally desired. I believe that the one prepared by Professor Williams on the Devonian formations of North America, is in form and substance of such a nature as to elucidate some of the principles which should guide in the preparation of geologic conventions. The paper which I prepared was brief, but was, I thought, pertinent to the subject in hand; but evidently it did not meet with the approval of the committee, for other reporters included the consideration of the Quaternary formations in their papers, that is, the members of the committee were determined that the Quaternary formations should be discussed in such a manner as to exhibit a supposed best classification, or at least such a one as they would recommend, all of which required a review of the general subject of the Quaternary formations of the country, and the more or less final settlement of many problems yet under discussion. Seeing that the report prepared by myself was, like that of Professor Williams, upon a general theory of precedure different from that held by most of the persons who were present at the meetings of the committee, I withdrew it at the time I resigned from the committee, and another member was appointed who prepared a paper more in harmony with the general views.

With regard to the papers which were actually published, that of Professor Williams is in harmony with my conclusions, and, I believe, germane to the purpose for which the committee was organized. The other papers are not germane to the proper function of the committee as understood by myself. To many of the opinions expressed I can agree, to many others I cannot, but to none of the papers is it proper that I should sign my name, because I am not the author of any one or part of one.

It will be noticed on examining the papers that a number of taxonomic schemes are presented. None of them are such as I would use, were I engaged in making a survey on the ground; and, futhermore, none of them are used by members of the United

States Geological Survey. It is, therefore, manifestly absurd that my name should be employed in their support, and that I should thus be made virtually to condemn the work of all of my assistants actually engaged in works of survey throughout the United States.

Long experience and careful consideration of this subject have led me to the conclusion that no detailed taxonomic scheme can be adopted for the entire country; but that there are many geologic provinces, and that in each one a distinct taxonomic scheme is necessary in order properly to present the facts exhibited in nature. On the other hand, I believe that a general time scale can be adopted to which the taxonomic schemes of the several geologic provinces can be referred with greater or less certainty. The general classification of the formations of each geologic province must be constructed and reconstructed with the course of investigation, and it should not be hampered with preconceived classifications; but geologists may well be furnished with a purely artificial or conventional time scheme to be used in the progress of their work.

A system of geologic conventions in common usage throughout the world seems to be desirable for two potent reasons: first, geologists will be able thus to understand one another's work with a great saving of labor and time; and second, a common language of geology will make the science available to a much larger number of people, and its beauties and truths may soon become the common property of all educated people. But how shall a universal system of conventions be established? If by direct agreement through a congress of the world's active workers in geology, it may be a compromise and may not be the very best. On the other hand, any good universal system is better than the multiform systems now in use. To be established as a general system, it must meet with very general if not universal acceptance, and no system should be promulgated which has a large number of opponents, lest it add to the confusion.

There is another method by which a general system may be secured. Geologists may go on devising, amending, and improving their systems severally, each new worker adopting such a system as he may think best; until at last, by a course of intelligent selection, a common system is evolved. A system evolved in this manner can be reached only in the distant future, and in the meantime the disadvantages of diverse systems will retard investigation and keep the science more or less buried from the general public under a cloud of conventions. Whether a system shall be formulated by enactment or evolved by practice is a question worthy of consideration. The legislative method may be tried, and if it fails the judicial method remains.

The following is the abstract of my report to the committee.—The full report was never completed.

The Quaternary or Pleistocene period is represented by all those

rocks which have been formed since the beginning of the glacial epoch. As thus defined they will probably include some rocks which have been called Pliocene.

The theory of the fundamental or principal classification of these rocks which has actually obtained in the world differs materially from that of the classification of all other clastic formations; as they are primarly classed by agencies and conditions of genesis.

Progress has been made in classifying the glacial deposits chronologically, and in classifying some of the lacustrine and marine pleistocene deposits chronologically by correlating them with the glacial epochs, or by a study of their fossils; but it is worthy of emphasis that the fundamental classification of all the rocks of this period is one based on genesis.

The series of geological events that constitute the history of the glacial epoch in North America are exceedingly varied and interesting. The great ice sheet that advanced from polar regions into middle latitudes, and then retreated and again advanced and retreated, was a dominant geological agency, and about its history all other phenomena are grouped. These phenomena are found in the records of a great number of lakes, many of which have disappeared, and in marine deposits which mark the sites of old shores and which are intimately related to the glacial deposits. In the Mississippi Valley the deposits of loess extend nearly to the Gulf of Mexico, and these formations are probably in part of glacial origin, and they have many intimate relations with the deposits wholly glacial. The deformations of the surface by diastrophic agencies through the glacial period are many and profound, and their history is recorded in a variety of base-level formations. When these facts are all recorded a history of the glacial period can be constructed which will be of profound importance as an integral chapter in the history of the earth, the principles of which will be extended to all the chapters of the volume. In northern latitudes glacial phenomena prevail. In southern latitudes many other phenomena can be correlated in time with glacial facts, because glacial action was projected far southward along mountain ranges and about isolated mountains, and because the glacial sediments of the Atlantic coast extend far southward and their histories are interwoven with the history of the sediments derived from more southern rivers and shores; and finally, because glacier-prepared sediment was carried into the valley of the Mississippi and spread far toward the Gulf.

The classes usually recognized in practice by geologists of this country are as follows:

1. Formations of fluviatile origin, otherwise called "flood-plain deposits," or alluvial deposits.
2. Formations of lacustrine origin, or lake deposits.
3. Formations of oceanic origin, or marine deposits along shore.
4. Formations due to the agency of torrents, a large part of which have been called alluvial fans or alluvial cones.

5. Formations of eolian origin, as sand-dunes.
6. Formations in swamps and marshes, as peat-bogs.
7. Formations in deltas, which are in part fluviatile and in part marine or lacustrine.
8. Formations of glacial origin.
9. Formations usually designated as Loess, which by some have been considered eolian; but later investigations seem to show that Loess is formed in part, at least, of glacier-ground rock-flour deposited in quiet waters.
10. Formations called soils and sub-soils, which cover the greater part of the surface of the land.

The Quaternary formations have proved to be of prime importance, because the principles of geology derived from their investigation constitute a large body of the doctrines applied in the study of the older formations. The rocks are also of great interest, and have been and will be studied in great detail, because of their industrial importance, and because, being at the surface, they are open to view, and ever present questions of interest even to the passing observer.

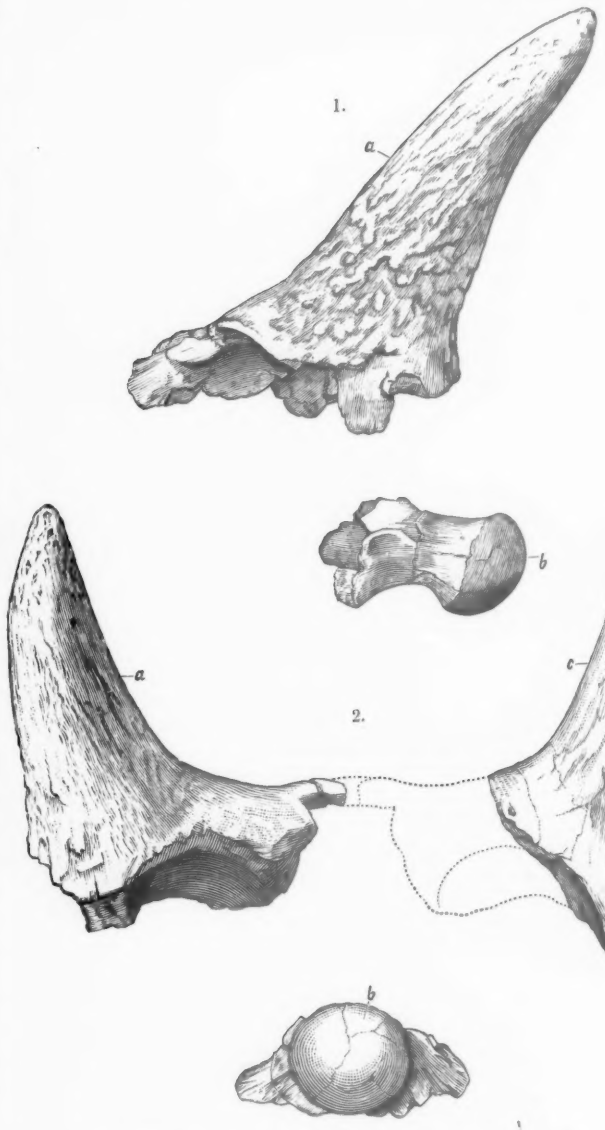
These formations represent a period or constitute a system in the proper sense of that term; and the period is distinguished from all others because the formations are classified on a distinct basis, because they overlie all other formations and cover the entire extent of lands, and because the general principles of geology are mainly derived from their study.

All of the great genetic classes which have been mentioned, except, perhaps, the Loess, have been divided into subordinate parts, for each one of which some conventional sign is necessary in the preparation of Quaternary charts. It will thus be seen that a special system is necessary for their representation.

Yet another fact must be considered in this connection. The Quaternary formations cover, to a greater or less extent, all other formations; and the chart designed to represent the distribution of older formations cannot be used to represent the Quaternary formations without imposing one system of conventional symbols upon another. The attempts to do this have not been generally successful, and it has been and will be found that special Quaternary maps are necessary, and a system of cartographic conventions must be devised for this purpose also.

The conclusions reached in the foregoing statements are as follows:

1. The Quaternary or Pleistocene formations represent a distinct period or system.
2. The Quaternary period should be defined as beginning with the glacial epoch.
3. The Quaternary formations are fundamentally classified by agency and condition of origin.
4. A cartographic scheme is necessary for the representation of Quaternary formations.



CERATOPS MONTANUS, Marsh One-fourth natural size.

APPENDIX.

ART. L.—*A New Family of Horned Dinosauria, from the Cretaceous;* by O. C. MARSH. (With Plate XI.)

DURING the past season, a special effort has been made by one field-party of the U. S. Geological Survey, to explore the Laramie formation, more particularly in Dakota and Montana. In this work, important collections of vertebrate fossils have been secured, and among them are remains of some new Dinosaurs of much interest, one of which is briefly described below.

Ceratops montanus, gen. et sp. nov.

The present genus appears to be nearly allied to *Stegosaurus* of the Jurassic, but differs especially in having had a pair of large horns on the upper part of the head. These were supported by massive horn-cores firmly coössified with the occipital crest. The latter are probably attached to the parietal bones, but, as the sutures in this region are obliterated, they may be supported in part by the squamosals.

The horn-cores in the type specimen are sub-triangular at base, but nearly round in section in the upper half. Their position is represented approximately in the figures of the accompanying plate. These horn-cores are slightly hollowed at the base, but are otherwise solid. The exterior texture and markings show that they were evidently covered with true horns, and these must have formed large and powerful offensive weapons.

In position and direction, these horn-cores are somewhat similar to the large posterior pair of protuberances in *Meiolania*, one of the extinct *Testudinata*, and to the corresponding ones of the existing *Phrynosoma*. The only known example of similar structure in the *Dinosauria* is the single median horn-core on the nasals of *Ceratosaurus*, from the Jurassic. It is not improbable that there were other horn-cores on the skull in the present genus, but, of this, there is at present no positive evidence. A detached median prominence resembling a horn-core was found with some similar remains, but may pertain to an allied genus.

The resemblance in form and position of the posterior horn-cores to those of some of the ungulate mammals is very striking, and, if detached, they would naturally be referred to that group.

The basioccipital found in place with these horn-cores, and represented in plate XI (figures 1 and 2, *b*), is much elongated, and formed the entire occipital condyle. Its exact position with reference to the horn-cores could not be determined.

Teeth, vertebræ, and limb bones which probably belong to the present genus were all secured in the same horizon. They indicate a close affinity with *Stegosaurus*, which was probably the Jurassic ancestor of *Ceratops*.

Among other remains referred to the present reptile, but not found with the type specimen, are some peculiar, large dermal plates, in pairs, that indicate a well-ossified armor. These plates show indications of being covered, in part at least, with scutes, as in turtles. Their position cannot at present be determined.

The type specimen on which the present genus and species are based was found in place, in the Laramie deposits of the Cretaceous, in Montana, by Mr. J. B. Hatcher, of the U. S. Geological Survey. Other specimens apparently pertaining to the same species were secured in the same horizon of the same region.

Remains of the same reptile, or one nearly allied, had previously been found in Colorado, in deposits of about the same age, by Mr. G. H. Eldridge, also of the U. S. Geological Survey.

The associated fossils found with the present specimens are remains of other Dinosaurs, crocodiles, turtles, and fishes, mostly of Cretaceous types. The mollusks in the same beds indicate fresh-water deposits.

The fossils here described indicate a reptile of large size, twenty-five or thirty feet in length, and of massive proportions. With its horned head and peculiar dermal armor, it must have presented in life a very strange appearance.

The remains at present referred to this genus, while resembling *Stegosaurus* in various important characters, appear to represent a distinct and highly specialized family, that may be called the *Ceratopsidæ*. They will be described more fully in a later number of this Journal.

Yale College, New Haven, Conn., November 23, 1888.

Explanation of Plate XI.

Figure 1.—Horn-core and basioccipital of *Ceratops montanus*, Marsh; side view. *a*, horn-core; *b*, basioccipital.

Figure 2.—Horn-cores and basioccipital of same skull; posterior view. *a*, left horn-core; *b*, basioccipital; *c*, right horn-core.

Both figures are one-fourth natural size.

INDEX TO VOLUME XXXVI.*

A

Academy, Connecticut, Transactions, 303; National, New Haven meeting, 475.
Alexander, J. M., Mt. Loa in 1885, 35.
Association, American, 78, 297; British, 396.

B

Barbour, E. H., tortoise (*Chrysemys picta*) with two heads, 227.
Barker, G. F., chemical notices, 60, 150, 383, 465.
Barus, C., electrical relations of platinum alloys, 427; viscosity of solids, 178; energy in permanent strains, 468.
Bell, L., effect of magnet on chemical action, 39.
Bennett, J H., Plants of Rhode Island, 394.
Blair, A. A., Chemical Analysis of Iron, 387.
Blanford, W. T., Fauna of British India: Pt. I, Mammalia, 297.
Botanical Works Noticed—American Woods, Hough, 160. Works of George Engelmann, 76. Catalogue of Plants of Middlesex Co., Mass., Dame and Collins, 392; near Niagara Falls, Day, 395; of Nantucket, Mass., Owen, 393; of Rhode Island, Bennett, 394; of Vermont, Perkins, 394. Contributions to American Botany, Watson, 392.
Botany Assimilation by colored leaves, Engelmann, 159. Bombaceæ, comparative anatomy, Dumont, 75. Color granules in flowers and fruits, 472. Glycerin and certain tissues, de Vries, 158. Heather in Townsend, Mass., Ball, 295. Malvaceæ, comparative anatomy, Dumont, 75. Secretions, origin of canals and receptacles for, LeBlois, 76. Sterculiaceæ, comparative anatomy, Dumont, 75. Tiliacæ, comparative anatomy, Dumont, 75. Vegetable histology, 75; physiology, 158. See further under Geology.
Brigham, W. T., Mt. Loa in 1880, 33.
Britton, N. L., Archæan areas of N. J. and N. Y., 71.

C

Calorimeter, ether, Neesen, 293.
Chamberlin, B. B., Minerals of New York County, 392.
Chatard, T. M., analyses of alkali lake waters, 146.
Chemical Works Noticed—Chemical Analysis of Iron, Blair, 387. Modern Theories of Chemistry, Meyer, 60.
Chemistry—Aluminum chloride, vapor density, Friedel and Crafts, 465. Carbon atom and valence, V. Meyer and Riecke, 386. Carbon dioxide in freezing mixtures, Cailletet and Colardeau, 465. Coal, heat of combustion, Schuerer-Kestner, 466. Elements and meta-elements, Crookes, 63. Hydrofluoric acid, vapor-density, Thorpe and Hambly, 385. Hydrogen sulphide, action on arsenic acid, Branner and Tomicek, 62. Molecular weights, method for determining, Raoult, 384. Nitrogen peroxide, molecular weight, Ramsay, 150. Oxygen, spectrum, Janssen, 385; valence, Heyes, 385. Phenylthiocarbimide, use in optical work, Madan, 388. Potassium, wave-length of red lines, Deslandres, 467. Solubility and fusibility, Carnelley and Thomson, 383. Valence, experiment to illustrate, Lepsius, 62.
Clarke, F. W., Constants of Nature, 303.
Collins, F. S., Flora of Middlesex Co., Mass., 392.
Color photometry, Abney, 292.
Crosby, W. O., Black Hills, Dak., 153.
Current, electric, effect of magnetic force on equipotential lines of, Hall, 131, 277.
Currents, alternating, measurement of, Kennelly, 453.

D

Dana, E. S., Beryllonite, a new mineral, 290.
Dana, J. D., changes in Mt. Loa craters: Pt. II. Mokuaweoweo, 14, 81, 167; brief history of Taconic ideas, 410.
Dame, L. L., Flora of Middlesex Co., Mass., 392.

* This Index contains the general heads Botany, Chemistry, Geology, Minerals, Obituary, Books, Zoology, and under each the titles of Articles referring thereto are mentioned.

Day, D. F., Catalogue of Plants near Niagara Falls, 395.
Day-light, penetration in water, Fol and Sarasin, 67.
Delgado, J. F. N., Bilobites, etc., de Portugal. Supplement, 154.
Dodge, W. W., localities of fossils in Mass., 56, 476.
Dumont, A., comparative anatomy of Malvaceæ, Bombaceæ, Tiliacæ, etc., 75.
Dunnington, F. P., deposits of oxides of manganese, 175.

E

Eakins, L. G., two sulphantimonites, Col., 450.
Eclipse expedition in Japan, Todd, 474.
Electrical discharges in gases and flames, Wiedemann and Ebert, 467; field, effect of moving dielectric in, Röntgen, 467.
Electricity and Light, Rayleigh, 460.
Electrolysis by alternating currents, Maneuvrier and Chappuis, 152; of water, von Helmholtz, 293.
Electro-magnetic waves, interference, Fitzgerald, 387.
Engelmann, G., Botanical Works, 76.
Energy and vision, Langley, 359.
In permanent strains, Barus, 468.
Entomology for Beginners, Packard, 297.

F

Fluorescence, Walter, 67.
Fossil, see GEOLOGY.

G

Galvanometers, mirror, mode of reading, Willson, 50.
Genealogical tree in paleontology, Judd, 154.
Geological Congress, International, London, 79, 389; American Report to, 469, 476*a*; American Organizing Committee for the Philadelphia meeting, 468.
Geological fund, Hayden memorial, 79.
GEOLOGICAL REPORTS AND SURVEYS—New Jersey, 1887, 71; Ohio Economic Geology, vol. VI, 68; Pennsylvania, 1886, 153; Portugal, 154.
Geological Society, American, 294; London, medals of, 79.
Geological and scientific bulletin, 154.
GEOLOGY—
Alkali-lake waters, Chatard, 146.
Antlitz der Erde, vol. ii, Suess, 72.
Archæan areas of N. J. and N. Y., Britton, 71; plant (*Archæophyton Newberryanum*), Britton, 71.
Bilobites de Portugal, Delgado, 154.
Black Hills, Dak., Crosby, 153.
Calamites, fructification of, Williamson, 71.
Cambrian fossils, Walcott, 161; trilobites from Sardinia, Meneghini, 294.
Ceratops montanus, Marsh, 477.
GEOLOGY—
Cortlandt series, Williams, 254; extension of, Kemp, 247.
Cretaceous Dinosauria, horned, Marsh, 477.
Eozoon Canadense, Dawson, 390.
Fauna of British India, Pt. I., Mammalia, Blanford, 297.
Florida, structure of, Johnson, 230.
Formes du Terrain, de la Nõë, 390.
Fossil plants and Potomac formation, Ward, 119.
Fossils in Mass., Dodge, 56, 476.
Iron sulphides, decomposition of, Julien, 295.
Manganese, deposits of, Dunnington, 175.
Mesozoic Mammalia, Osborn, 390; plants, Newberry, 70.
Metamorphism, contact, near Peekskill, Williams, 254.
Paläophytologie Solms-Laubach, 72.
Platyceras, sedentary habits of, Keyes, 269.
Puget Group, Wash Terr., White, 443.
Rhætic plants from Honduras, Newberry, 342.
Soil from Wash. Terr., analysis, Schneider, 236.
Taconic, Dana, 410.
Theoretische Geologie, Reyer, 389.
Trias of N. J. and Conn. Valley, Fauna and Flora of, Newberry, 70.
Williamsonia angustifolia, Nathorst, 391.
Goodale, G. L., botanical notices, 75, 158, 392, 472.
Gravity, variations in Hawaiian Is., Preston, 305.
Gray, A., list of writings and index, Appendix.
Guerne, J. de, Excursions Zoologiques, etc., 77.
Gulf Stream explorations, Pillsbury, 225.
Gun-cotton, effects of detonation, Munroe, 48.

H

Hall, E. H., effect of magnetic force on equipotential lines of electric current, 131, 277.
Hallock, W., flow of solids: a note, 59.
Hayden memorial geological fund, 79.
Heat measurement, von Helmholtz, 292.
Hidden, W. E., Edisonite, 272; mineralogical notes, xenotime, 380; auerlite, 461; sulphohalite, 463.
Hinman, R., Eclectic Physical Geography, 303.
Hough, R. B., American Woods: Pt. I, 160.
Hovey, E. O., cordierite-gneiss from Conn., 57.

I

Iddings, J. P., origin of quartz in basalt, 208; Translation of Rosenbusch's Micr. Physiography of Rock-making Minerals, 471.
India in 1887, Wallace, 302.
Insect Life, new periodical Bulletin, 296.
Irelan, W., Mineralogical Report of California, 1887, 73.

J

Japan, volcanic eruptions in, 104, 293.
Jerofeieff, M., Der Meteorit von Nowo-Urei, 74.
Johnson, L. C., structure of Florida, 230.
Jordan, D. S., obituary of S. Stearns, 303.
Joubert, J., Electricity and Magnetism, 68.
Journal of Morphology, 395.
Judd, J. W., Eruption of Krakatoa, 471.

K

Kemp, J. F., Rosetown extension of Cortlandt series, 247.
Kennelly, A. E., voltametric measurement of alternating currents, 453.
Keyes, C. R., sedentary habits of Platyceras, 269.
Kokscharow, N. von, Mineralogie Russlands, vol. X, 74.
Kunz, G. F., mineralogical notes, 222; new meteoric irons, 275; phenacite in N. England, 472.

L

Langley, S. P., Energy and vision, 359; invisible solar and lunar spectrum, 397.
Latschinoff, P., Der Meteorit von Nowo-Urei, 74.
LeBlois, A., origin and development of canals and receptacles for secretions, 76.
Light and Electricity, Rayleigh, 468; penetration of, in lake waters, Fol and Sarasin, 67.
Lindgren, W., mineralogy of Pacific coast, 73.
Long, J. H., circular polarization of tartrate solutions, 351.

M

Mackintosh, J. B., on auerlite, 461; on sulphohalite, 463.
Magnet, effect on chemical action, Rowland and Bell, 39.
Marsh, O. C., new horned Dinosauria, 477.
Mascart, E., Electricity and Magnetism, 68.
Meneghini, G., Cambrian trilobites of Sardinia, 294.
Merriam, C. H., fauna of Great Smoky Mts.; and description of a new species of red-backed mouse, 458.
Merrill, G. P., Fayette county meteorite, 113.
Metals, index of refraction, Kundt, 151.
Meteoric iron, Bendego, Brazil, 158; Burke Co., N. C., Kunz, 275; Laramie Co., Wy., Kunz, 276; Santa Catarina, Brazil, 157.
Stone, Nowo-Urei, Russia, 74; Fayette Co., Texas, Whitfield and Merrill, 113.
Meteorites, Brazilian, Derby, 157; orbits of, and earth's orbit, Newton, 1.
Meyer, L., Modern Theories of Chemistry, 60.
Mineralogical Report of Cal., 1887, Irelan, 73.
Mineralogie Russlands, Kokscharow, 74.
Mineralogy of Pacific Coast, Lindgren, 73.
Minerals—Amarantite, analysis, 156. Apatite, N. Y., 223. Aragonite pseudomorph, 224. Auerlite, new, 461. Barium feldspar, Pa., anal., 326. Bertrandite, Col., analysis, 52. Beryl, anal., 317. Beryllonite, new, preliminary notice of, 290. Bückingite, new, 156. Cassinite, anal., 326. Chert, Hinde, 73. Cyanite, N. Carolina, 224 Diamond in a meteorite, 74. Dumortierite, Norway, 73. Edisonite, new, 272. Feldspar, barium, anal., 326. Gahnite, Mass., 157. Hohmannite, new, 156. Horsfordite, new, 156. Iolite in gneiss, 57. Kotschubeite, 73. Lausfordite, new, 156. Marcasite, 295. Mazapilite, new, 391. Monazite, N. C., anal., 322. Oligoclase, N. C., anal., 222, 324. Phenacite, Col., anal., 320; New Hampshire, 222, 472. Phlogopite, N. Y., anal., 329. Psilomelane, formation, 175. Pyrite, decomposition of, 295. Quartz, origin of, in basalt, Iddings, 208; pseudomorphs after spodumene, 222; twin crystals, 323. Quenstedtite, new, 156. Riebeckite, new, 391. Sulphantimonites, Col., Eakins, 450. Sulphohalite, 463. Sussexite, N. J., anal., 323. Uraninite, 295. Vesuvianite, Mass., 157. Xenotime, New York City, 380; N. C., 381, 382. Xenotime-zircon, N. C., 381, 382. Zircon, North Carolina, 73.
Moler, G. S., vibrations of cords, etc., 337.
Morphology, Journal of, 395.
Munroe, C. E., effects of detonation of gun-cotton, 48.

N

Natural History Society, New Brunswick, Bulletin, No. vii, 160; Trenton, Journal of, 160.
Newberry, J. S., Fauna and Flora of N. J. and Conn. Valley Trias, 70; Rhætic plants from Honduras, 342.
Newton, H. A., relation of orbits of meteorites to the earth's orbit, 1.
Noë, G. de la, Les Formes du Terrain, 380.

O

Obituary—Chamberlin, Benjamin B., 396; Clausius, R., 304; Debray, Henri, 304; Gosse, Philip Henry, 304; Hager, Albert D., 226; Irving, Roland D., 80; Lewis, Henry Carvill, 226; Proctor, Richard A., 304; Stearns, Silas, 303; Stevenson, James, 226; Worthen, A. H., 80, 161.
Observatory, Lick, 78.
Osborn, H. F., structure and classification of the Mesozoic Mammalia, 390.
Owen, M. L., Plants of Nantucket, Mass., 393.

P

Packard, A. S., Entomology for Beginners, 297.
Penfield, S. L., Bertrandite, Mt. Antero, Col., 52; mineralogical notes, 317.
Perkins, G. H., Catalogue of the Flora of Vermont, 394.
Pillsbury, J. E., explorations of the Gulf Stream, 225.
Pitcher, F. B., absorption spectra of blue solutions, 332.
Polarization, circular, of tartrate solutions, Long, 351.
Preston, E. D., deflection of plumb-line and variations of gravity, Hawaiian Is., 305.

R

Radiophone, electro-chemical, Chaperon and Mercadier, 153.
Rayleigh, Light and Electricity, 468.
Reyer, E., Theoretische Geologie, 389.
Rock-forming minerals, Rutley, 295.
Rocks—Cordierite gneiss, Conn., Hovey, 57. Cortlandt series, Kemp, 247; G. H. Williams, 254. Igneous, Teall, 154. Krakatoa, Judd, 471. Microscopical Physiography of, Iddings-Rosenbusch, 471.
Rosenbusch, Microscopical Physiography, translation by Iddings, 471.
Rowland, H. A., effect of magnet on chemical action, 39.
Rutley, F., Rock-forming Minerals, 295.

S

Schneider, E. A., analysis of a soil from Washington Terr., 236.
Sherburn, C. D., Bibliography of Foraminifera, 295.
Smithsonian Institution, Annual Report, 78.
Solids, flow, Hallock, 59; powdered, compression, Spring, 286; viscosity, Barus, 178.
Solms-Laubach, G. zu, Einleitung in die Paläophytologie, etc., 72.
Solutions, blue, absorption spectra, Pitcher, 332; tartrate, circular polarization, Long, 351.
Spectra, absorption, of blue solutions, Pitcher, 332; ultra violet, of metalloids, Deslandres, 388.
Spectroscope, Index to Literature of, Tuckerman, 303, 388.
Spectrum analysis, Grünwald's hypothesis, 67; infra red solar, Abney, 291; invisible solar and lunar, Langley, 397; of oxygen, Janssen, 385.
Sperry, E. S., mineralogical notes, 317.
Spring, W., compression of powdered solids, 286.
Strains, energy in, Barus, 468.
Suess, E., Das Antlitz der Erde, vol. ii, 72.

T

Teall, J. J. H., British Petrography, 154.
Todd, D. P., Amer. Eclipse Expedition to Japan, 474.
Torsion, resistance of bars to, Dewar, 152.
Trowbridge, J., physical notices, 66, 151, 292, 387, 467.
Tuckerman, A., Index to the Literature of the Spectroscope, 303, 388.
Tuckerman Memorial Library, 476.

V

Vibrations, transverse, of cords and wires, Moler, 337.
Volcano, eruption of, in Japan, Mansfield, 293. Kilauea and Mt. Loa (Mokuaweoweo), Dana, 14, 81, 90, 167; Mokuaweoweo, 1880, 1885, Brigham and Alexander, 33; in New Zealand and Krakatoa, Dana, 104; of Krakatoa, Judd, 471.
Vries, A. H. de, glycerin in its relations to certain tissues, 158.

W

Walcott, C. D., Cambrian fossils from Mt. Stephens, 161.
Wallace, R., India in 1887, 302.
Ward, L. F., fossil plants and the Potomac formation, 119; geological notices, 71, 391.
Water, electrolysis of, von Helmholtz, 293; latent heat of evaporation, Dieterici, 152.
Watson, S., Contributions to American Botany, 392.
Wave-length, of red lines of potassium, Deslandres, 467.
Waves, electro-magnetic, interference, Fitzgerald, 387.
White, C. A., Puget Group of Washington Terr., 443.
Whitfield, J. E., Fayette Co. meteorite, 113.
Williams, G. H., contact-metamorphism near Peekskill, N. Y., 254.
Williamson, W. C., fossil plants of Coal Measures: Pt. xiv, fructification of Calamites, 71.
Willson, R. W., mode of reading mirror galvanometers, 50.

Z

Zoological excursions in Fayal and San Miguel, Guerne, 77.
Zoology—
Fauna of Great Smoky Mts., Merriam, 458.
Foraminifera, Recent and Fossil, Bibliography of, Sherburne, 295.
Red-backed mouse (*Evotomys Carolinensis*) Merriam, 458.
Tortoise (*Chrysemys picta*) with two heads, Barbour, 227.
See further under Geology.

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Wulfenite Red.—Another hard trip to the Red Cloud mine enabled us to secure some specimens that the superintendent had been saving for us for over a year. We were there in July and under date of September 27th, he writes us: "That he is sorry to say they have found no more Wulfenites."

As the district is now almost entirely abandoned, and no more good specimens are now found at the mine, we were very glad to secure these, having sold all taken to Europe. Large specimen groups, $1.00 to $25.00; fragments and crystals, 5 cents to $1.50.

In *New Mexico* we were very fortunate in striking a pocket of brilliant *yellow Wulfenite* equal to the best ever found at Eureka, Nevada. It is associated with flos ferri. The thin and delicate plates are very beautiful. Specimens, $2.00 to $10.00; fragments, brilliant, 10 cents to $1.50.

From the Copper Queen mine and from Morenci we have obtained the finest *Azurites* and *Malachite pseudomorph after Azurite* ever seen.

Malachite fibrous in beautiful surfaces and tufts, 5 cents to $5.00; same penetrating clear calcite, 25 cents to $10.00; Malachite polished, 50 cents to $3.00; Malachite and Azurite banded in a charming manner, 75 cents to $5.00.

Chrysocolla, with a very lustrous fracture, the finest ever seen, 10 cents to $5.00.

Cuprite, brilliant, 5 cents to $3.00, some blood red, 50 cents to $5.00.

Mexican Minerals.

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Opals.—We have brought back from Mexico this time the finest lot of these we have ever seen for sale. We have them of all kinds, *precious* or *noble, fire, harlequin, milky, opal agate, opal with inclosures, hyalite,* etc., etc., cut and in the rough, from 5 cents to $50.

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The *Twin Calcites* that we got from Guanajuato are more interesting in form than any we ever got before.

Apophyllite, 12½ x 10 inches, very fine surface entirely covered with large crystals, $50.00. Smaller, 25 cents to $10.00. Rose colored *Apophyllite,* $3.50 to $20.00.

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We again revisited the celebrated Turquois locality in New Mexico, and have some of the finest deep blue pieces we have ever seen, 10 cents to $7.50 each.

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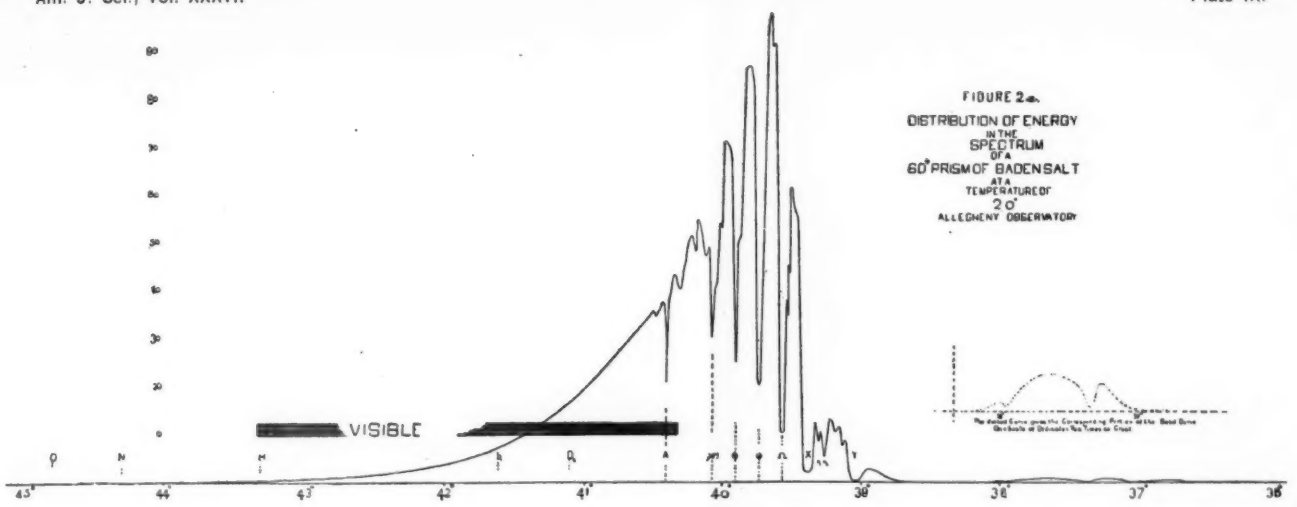
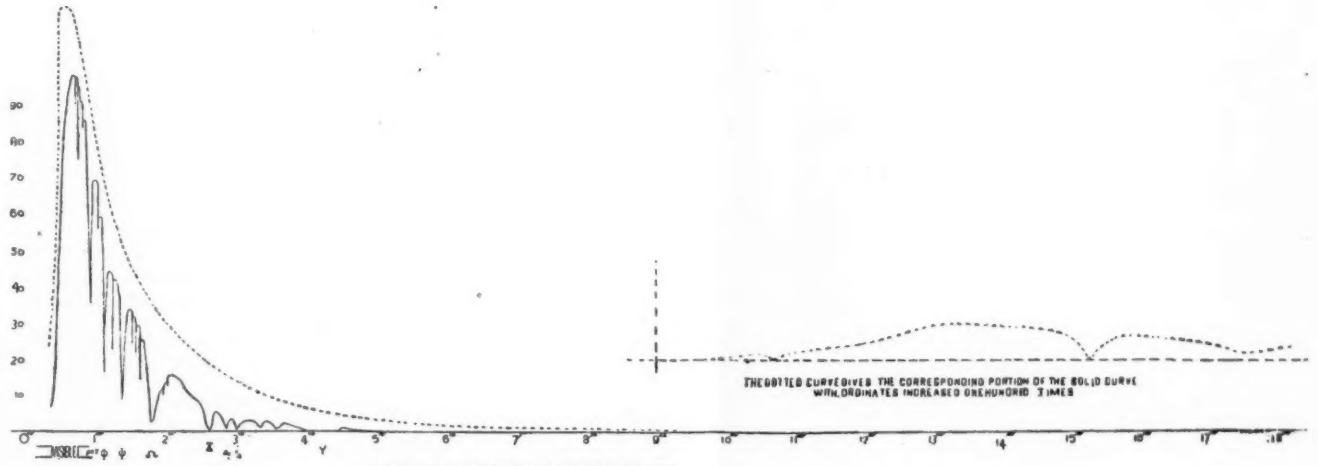
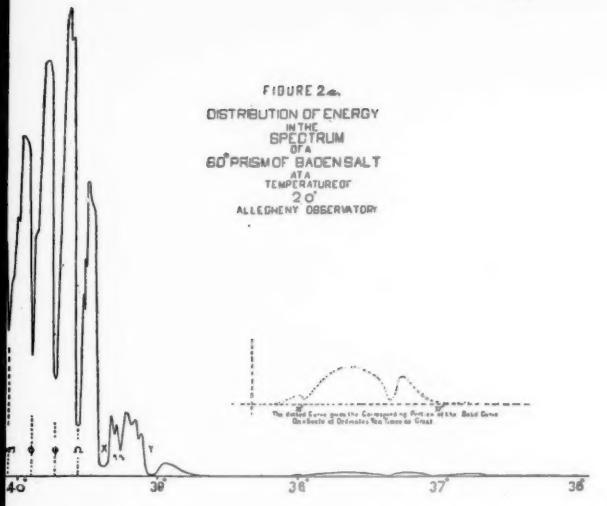


FIGURE 2a.
DISTRIBUTION OF ENERGY IN THE SPECTRUM OF A 60° PRISM OF BADEN SALT AT A TEMPERATURE OF 20° ALLEGHENY OBSERVATORY



NORMAL ENERGY SPECTRUM
FIGURE 2 b



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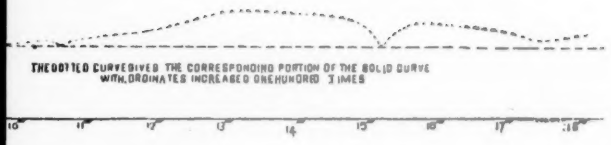

THE DOTTED CURVE GIVES THE CORRESPONDING PORTION OF THE SOLID CURVE WITH ORDINATES INCREASED ONE HUNDRED TIMES

NORMAL SPECTRUM TO 5μ.

FROM STUDIES MADE WITH THE BOLOMETER IN 1886, AT THE ALLEGHENY OBSERVATORY.

S P LANGLEY

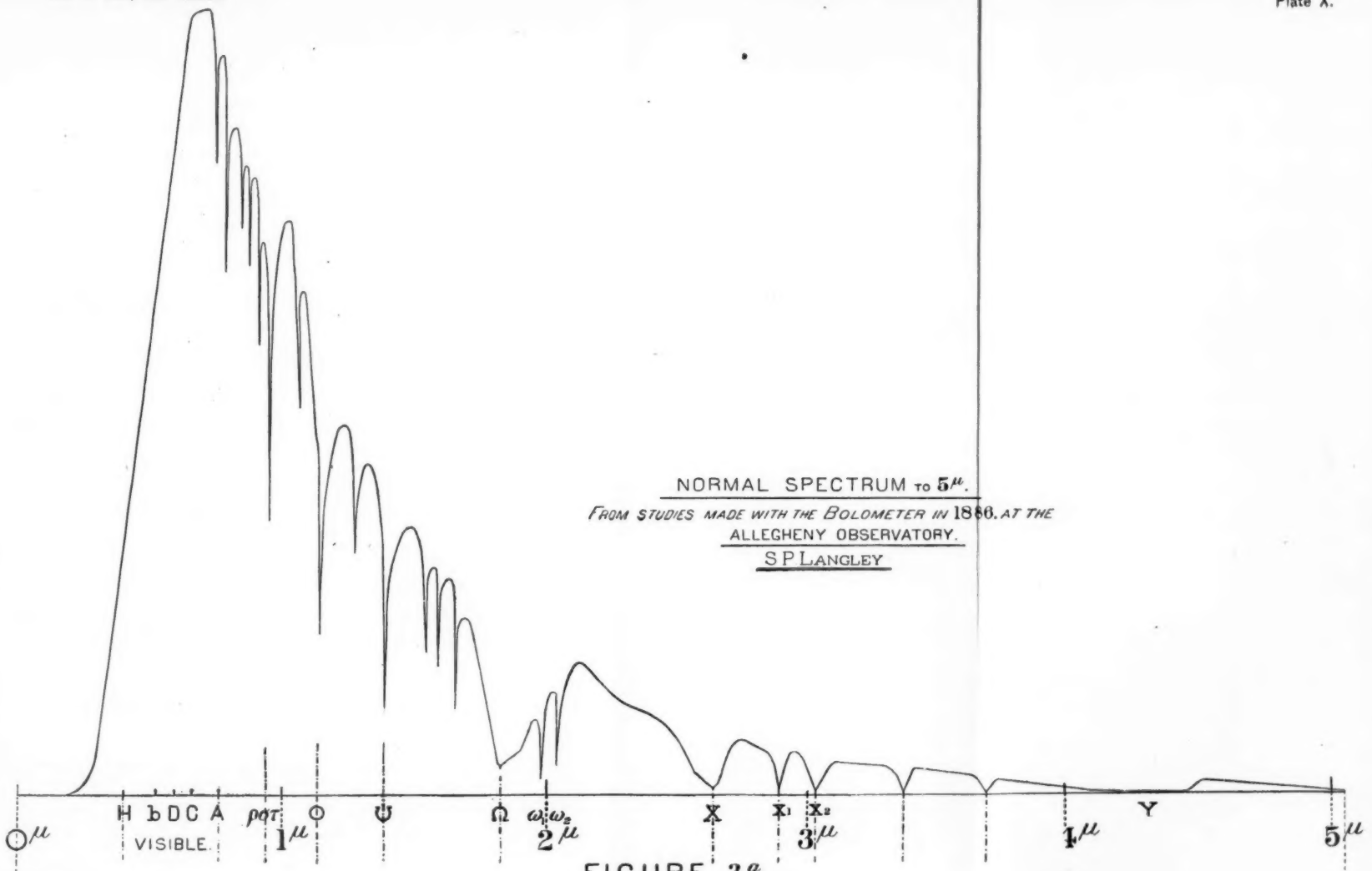

FIGURE 3a

FIGURE 3b.

MAL SPECTRUM to 5^{μ}.

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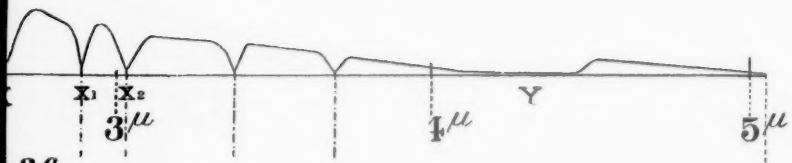

3a.

3b.

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To Binders—The Appendix consisting of the Gray Bibliography and Index should be put at the close of the volume.

CONTENTS.

Page

ART. XLI.—The Invisible Solar and Lunar Spectrum; by S. P. LANGLEY. With Plates IX and X 397

XLII.—A brief history of Taconic ideas; by J. D. DANA ... 410

XLIII.—Certain Generic Electrical Relations of the Alloys of Platinum; by C. BARUS 427

XLIV.—Puget Group of Washington Territory; by C. A. WHITE 443

XLV.—Sulphantimonites from Colorado; by L. G. EAKINS . 450

XLVI.—Voltametric Measurement of Alternating Currents; by A. E. KENNELLY 453

XLVII.—Fauna of the Great Smoky Mountains; by C. H. MERRIAM 458

XLVIII.—New Thorium Mineral, Auerlite; by W. E. HIDDEN and J. B. MACKINTOSH 461

XLIX.—New Sodium sulphato-chloride, Sulphohalite; by W. E. HIDDEN and J. B. MACKINTOSH 463

L.—Appendix: Horned Dinosaurs from the Cretaceous; by O. C. MARSH. With Plate XI 477

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics.—Vapor-density of Aluminum chloride, FRIEDEL and CRAFTS: Freezing mixtures containing solid Carbon dioxide, CAILLETET and COLARDEAU, 465.—Determination of the Heat of Combustion of Coal, SCHEURER-KESTNER, 466.—Wave-length of the Double red line in the spectrum of Potassium, DESLANDRES: Electrical discharges in gases and flames, E. WIEDEMANN and H. EBERT: Electrodynamic effect produced by the movement of a dielectric in an electrical field, W. C. RÖNTGEN, 467.—Light and Electricity, LORD RAYLEIGH: The energy stored in permanent strains, C. BARUS, 468.

Geology and Mineralogy.—International Congress of Geology, 468.—American Report to the International Congress of Geologists, 469.—Volcanic Phenomena of the Eruption of Krakatoa, J. W. JUDD: Microscopical Physiography of the Rock-making Minerals and aid to the microscopical study of rocks, H. ROSENBUSCH and J. P. IDDINGS, 471.—Phenacite in New England, G. F. KUNZ, 472.

Botany.—Color-granules in flowers and fruits, COURCHET, 472.

Miscellaneous Scientific Intelligence.—American Eclipse Expedition to Japan, D. P. TODD, 474.—National Academy of Sciences 475.—Note to Article VIII: Tuckerman Memorial Library, 476.

Communication on the American Report of the International Congress, J. W. POWELL, 476*a*.

INDEX TO VOLUME XXXVI, 479.